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GEOLOGY AND ORE DEPOSITS OF THE KERN RIVER URANIUM AREA, KERN COUNTY, CALIFORNIA*

By

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GEOLOGY AND ORE DEPOSITS OF THE KERN RIVER URANIUM AREA, KERN COUNTY, CALIFORNIA

By E. M. MacKevett, Jr.

ABSTRACT

In the Kern River uranium area, an area of approximately 30 square miles in northeastern Kern County, Calif., small uranium deposits are erratically distributed along fractures, most of them within the Isabella granodiorite. The deposits probably are too small and of too low grade to be worth mining on a large scale, but they contain local concentrations of ore. Uranium was first discovered in the area in January 1954, at the Miracle mine. Prior to 1956 four shipments of uranium ore, totalling about 189 tons, were made--two from the Miracle mine and two from the Kergon mine. The most valuable shipment was the first one from the Miracle mine, which consisted of 46 tons of ore containing 0.53 percent of uranium. The other shipments contained respectively, 0.14 percent, 0.18 percent, and 0.16 percent uranium.

The principal ore mineral is autunite, but minor amounts of sooty pitchblende, carnotite, and metazeunerite were found. Common gangue minerals are scarce or altogether lacking in most of the deposits, and wall-rock alteration is generally weak or absent.

Most of the deposits are believed to have formed in low-temperature, near-surface environments and to belong to Lindgren's epithermal class. There are numerous hot springs in the area and nearby, and some of these may have influenced uranium deposition. A possible alternative explanation for some of the deposits is that their constituent uranium

was derived from the Isabella granodiorite. This rock locally contains abnormal amounts of uranium, and it is conceivable that some uranium was leached from it and subsequently deposited in fractures.

Minor gold deposits, in both lodes and placers, and small tungsten deposits, associated with quartz veins or disseminated in tactite, also occur in the area.

INTRODUCTION

LOCATION AND ACCESSIBILITY

The Kern River uranium area, includes about 30 square miles in Tps. 26 and 27 S., Rs. 31 and 32 E., Mount Diablo Base and Meridian, in northeastern Kern County, California (fig. 1). The area is in the highly dissected southern Sierra Nevada and is included in the Sequoia National Forest. Its center is about 30 miles northeast of Bakersfield, from which it is accessible by State Highway 178. Its northern part is penetrated by several dirt roads, most of which are very rough. The nearest railroad shipping point and major supply source is Bakersfield, which is served by both the Santa Fe and Southern Pacific railways. The only settlement in the area is Miracle (formerly Hobo) Hot Springs, whose population is small.

GEOGRAPHY

The southern Sierra Nevada comprises several distinct ranges whose general trend is north. Their altitudes generally diminish from north to south, and at their southern ends the ranges curve southwestward and merge into the Tehachapi Mountains. This part of the Sierra thus presents a marked contrast to much of the central part, with its prominent crest, steep eastern escarpment, and long moderate western slope.

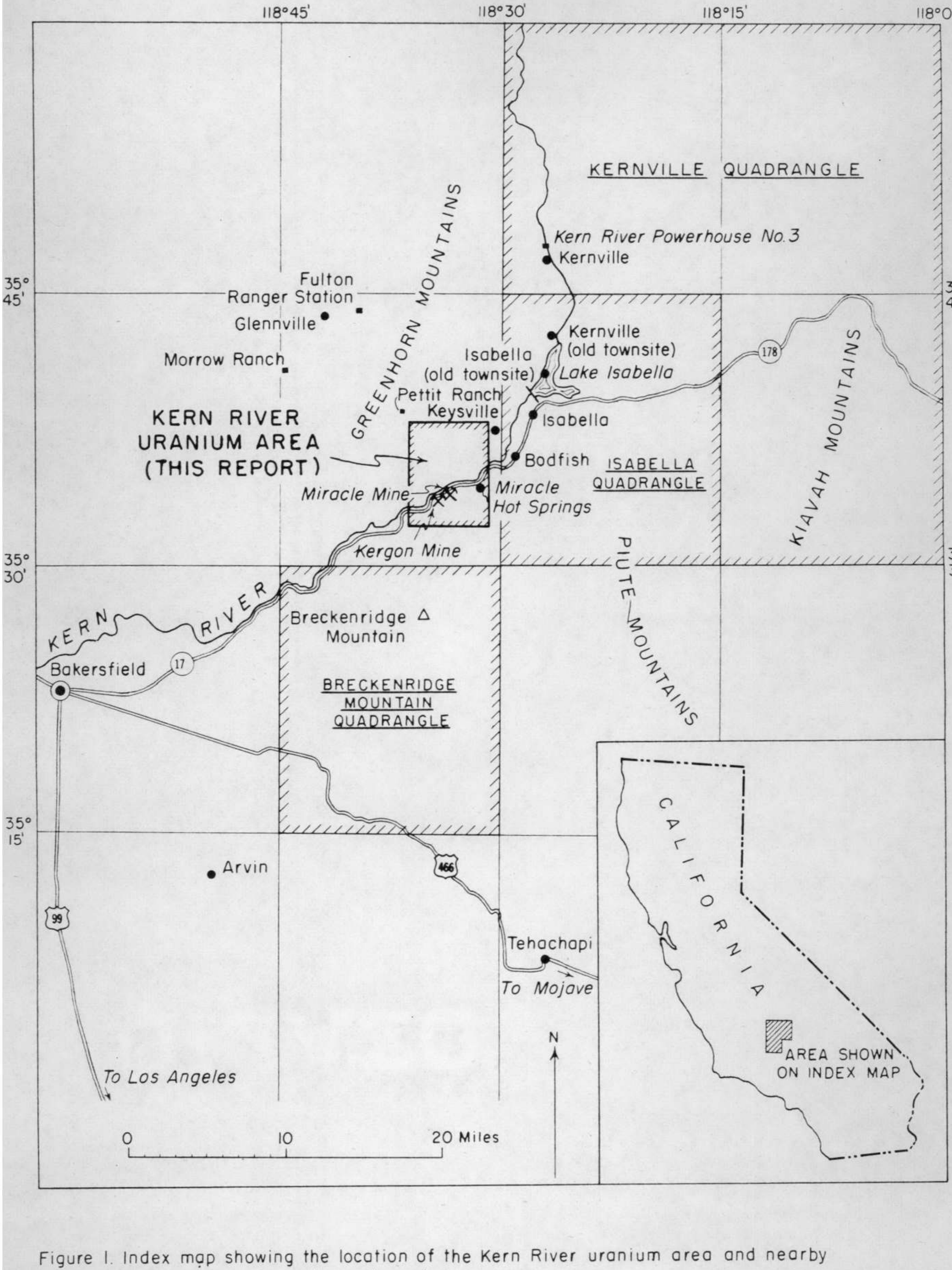


Figure 1. Index map showing the location of the Kern River uranium area and nearby geologically mapped quadrangles

In the Kern River uranium area, the Kern River crosscuts the general trend of the ranges in a deep gorge. Altitudes in the area range from about 2,100 feet in the Kern River Canyon to about 6,100 feet on the eastern slopes of the Greenhorn Mountains, one of the ranges in the southern Sierra Nevada. The Kern River is the master drainage artery. Several tributary streams, including Clear Creek, Greenhorn Creek, the stream occupying Black Gulch, and smaller unnamed streams are permanent, although their flow may be reduced to mere trickles by late summer. Springs, including some hot springs, are abundant in the general region, and several are within the mapped area.

The summers in the Kern River uranium area are hot and dry and the winters moderately cold. The annual precipitation probably ranges from about 5 inches in the lowest parts of the area to about 15 inches at the highest altitudes. Most of the precipitation occurs during winter storms, which generally deposit snow on the higher ground. In the summers, thunder storms produce a moderate amount of rain. Data from nearby weather stations, whose locations are shown in figure 1, are summarized in table 1.

The vegetation is controlled mainly by altitude and commensurate rainfall, and to a lesser extent by the character of the rocks. The commonest trees at moderate altitudes are digger pine, buckeye, and scrub oak, which characterize the greater part of the landscape. Conifers of several species grow at the higher altitudes, and sage brush and cacti predominate at the lower altitudes. Brush of various kinds, some forming dense thickets, abounds at intermediate and high altitudes. Willow, sycamore, cottonwood, and poison oak are common along streams.

Table 1.--Summary of climatological data from weather stations near the Kern River uranium area.-/ (Number of years recorded is shown in parentheses.)

Station	altitude (in feet)	avg annual temp (in °F)	max temp (in °F)	min temp (in °F)	annual precipitation (in inches)
Glennville (Fulton Ranger Station)	3540	-- --	-- --	-- --	12.64 (8)
Glenville (Morrow Ranch)	3270	52 (37)	99 (37)	10 (37)	13.56 (38)
Kern River Power House Number 3	2701	58.8 (1)	106 (1)	14 (1)	5.63 (1)
Kernville (Old townsite)	2565	-- --	-- --	-- --	4.45 (54)

-/ Data compiled from U. S. Department of Commerce, Weather Bureau, 1948, p. 351, 352, 355, 356, 365, 366.

PURPOSE AND SCOPE OF WORK

The purpose of this investigation was to determine the mode of occurrence, origin, and probable extent of the uranium deposits, to relate them to the regional geology, and to learn by a study of the geology of the area if it is likely to contain other uranium deposits, and if so where to seek them. The work was done by the Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

During three months allotted to field studies the geology of the entire area was mapped on a scale of 1:20,000 on National Forest Service aerial photographs, the geology of the areas around the Miracle and Kergon mines was mapped on a scale of 200 feet to the inch by plane-table methods, and the geology of the workings in the Miracle and Kergon mine areas was mapped on a scale of 20 feet to the inch by means of Brunton compass and tape. A scintillation counter was used to make detailed radioactivity surveys in the mine areas, and reconnaissance surveys throughout the remainder of the area.

Geologic data from the aerial photographs were compiled on a 1:20,000 topographic base prepared by the Topographic Division of the U. S. Geological Survey from the Glennville 15-minute quadrangle (in preparation). Laboratory work included petrographic studies of thin sections, and mineralogic investigations by means of heavy-media separations, oil immersion methods, and X-ray diffraction. An X-ray fluorescence spectrometer was used for partly determining the characteristic assemblage of elements in many ores and rocks, and semiquantitative spectrographic analyses, uranium assays, and age determinations were made on selected samples.

PREVIOUS WORK

Published geologic data on the Kern River uranium area consist of descriptions of the uranium mines and prospects by Walker, Lovering, and Stephens (1956), and brief descriptions of some gold and tungsten mines by the California State Division of Mines (Brown, G. C., 1915; Tucker and Sampson, 1940; Tucker, Sampson, and Oakeshott, 1949). W. A. Bowes and other geologists of the U. S. Atomic Energy Commission have investigated the Miracle and Kergon mines and the uranium prospects in the area, but the results of their work have not yet been published.

Several geologic reports on areas near the one here described have been published. Miller (1931), on the basis of reconnaissance mapping, has constructed two geologic sections across the southern Sierra Nevada. Miller and Webb (1940) have mapped the 30-minute Kernville quadrangle, and Dibblee and Chesterman (1953) have mapped the 15-minute Breckenridge Mountain quadrangle.

ACKNOWLEDGMENTS

W. A. Bowes and other Atomic Energy Commission geologists stationed at Bakersfield were extremely cooperative, both in discussing the geology of the uranium deposits and in making available the results of their investigations. Unpublished reports by the U. S. Corps of Engineers on the Isabella dam site and the Isabella quadrangle (see fig. 1) were available. Valuable help was given by mining people, especially C. S. Hale, president of the Great Lakes Oil and Gas Company, which owns the Kergon mine, R. L. Steele, formerly superintendent of the Kergon mine, and M. S. Patterson and John Yonde of the Miracle Mining Company. L. J. White assisted on the project for 2½ months and H. G. Stephens for 2 weeks.

GEOLOGY

GENERAL GEOLOGIC SETTING

The southern Sierra Nevada, in which the Kern River uranium area lies, consists predominantly of granitic rocks with local roof pendants of metamorphic rocks. The metamorphic rocks are remnants of a thick geosynclinal sequence, and consist mainly of mica schist and phyllite but include some quartzite, marble, and metavolcanic rock. Miller and Webb (1940, p. 350) estimate that these rocks are over 12,000 feet thick in the Kernville quadrangle, and Dibblee and Chesterman (1953, p. 19) believe that the thickest metasedimentary rock unit in the Breckenridge Mountain quadrangle is about 20,000 feet thick. Contacts between metamorphic and granitic rocks are mostly sharp, but in places they are gradational.

The batholithic rocks range from gabbro to granite but are preponderantly quartz monzonite, granodiorite, and quartz diorite. The most basic plutonic rocks--gabbro, diorite, and related types--are the oldest and were invaded and partly assimilated by later magmas. They occur chiefly in small isolated bodies or in zones of "mixed rock." Dikes of pegmatite and aplite cut the batholithic rocks and the metamorphic rocks. Tertiary and Quaternary rocks, chiefly terrestrial sedimentary deposits, locally flank the range.

The region is tectonically active and the site of many recorded earthquakes (Townley and Allen, 1939; Dibblee and Chesterman, 1953, p. 50; Oakeshott, 1955). Dibblee and Chesterman (1953, p. 50, 51) divide the southern Sierra Nevada into four fault-bounded structural blocks. In general, post-Nevadan structures conform to the hypothesis of Hill (1954, p. 9), who regards regional north-south shortening and east-west extension as the primary tectonic strain pattern for most of southern California. The major systems of shears are exemplified by the left-lateral[✓], northeast-trending Garlock and similar faults, and the northwest-trending, right-lateral[✓] San Andreas and related faults.

A segment of the Kern Canyon fault zone[✓], the most important structural feature of the general region, passes about a quarter of a mile southeast of the southeastern corner of the Kern River uranium area. According to Webb (1955, p. 35) the Kern Canyon lineament extends from the Tejon Hills in the southern San Joaquin Valley northeastward and northward for more than 100 miles, and includes the White Wolf, Breckenridge, Havilah Valley, Hot Springs, and Kern Canyon faults, probably as distinct segments (fig. 2).

The nature of the displacement has been established for some faults of this fault zone but is conjectural for others. Movement on the recently active White Wolf fault is mainly left-lateral (Hill, 1955, p. 40).

[✓] A left-lateral fault is a fault on which the side opposite a viewer had an apparent lateral displacement toward the viewer's left. Apparent lateral movement on the opposite block would be to the right in a right-lateral fault.

[✓] The Kern Canyon fault zone and its probable southwesterly extensions have been termed the Kern Canyon lineament by Webb (1955, p. 35).

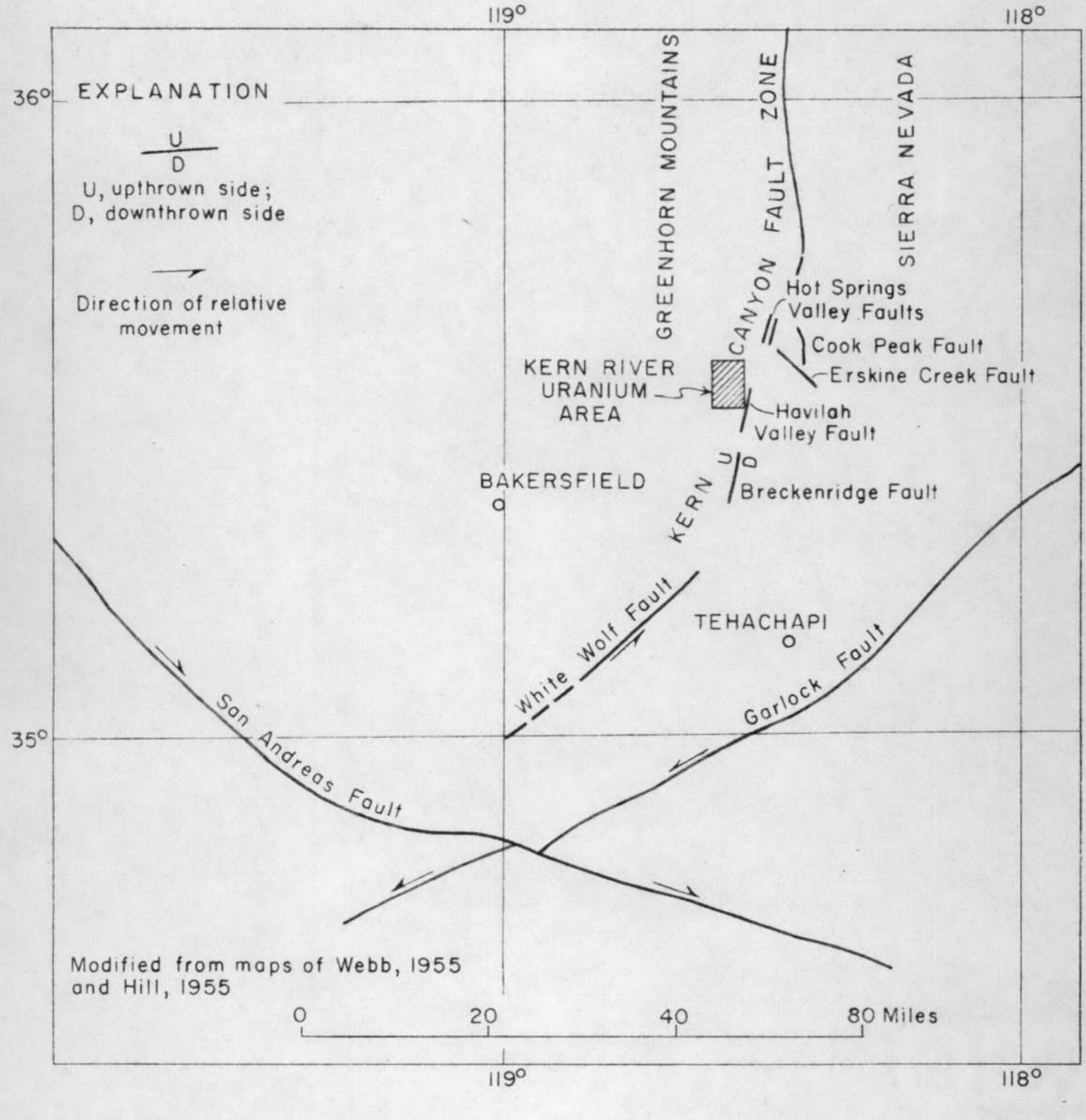


Figure 2. Map showing segments of the Kern Canyon fault zone and nearby major faults

The movement on the Breckenridge fault is believed to have been mainly or entirely vertical, the west block having been elevated at least 4,000 feet (Dibblee and Chesterman, 1953, p. 46). Treasher (1949b, p. 1957-1958) believes that the north-striking Kern Canyon fault is a high-angle west-dipping thrust fault north of Bodfish, and a high-angle east-dipping normal fault south of Bodfish. Near the Isabella dam site the crushed rock along Kern Canyon fault is 800 feet wide (Treasher, 1949a, p. 1946). Webb (1946, p. 362) believes that the Kern Canyon fault was probably developed during the Nevadan orogeny and that only its roots are now visible.

Treasher (1949b) has described other major faults in the Isabella quadrangle, including the Cook Peak fault, which is a south-trending split from the main Kern Canyon fault, and the northwest-trending Erskine Creek fault. Miller (1931, p. 335) and Hake (1928, p. 1028) believe there is a major north-trending fault along the west flank of the Greenhorn Mountains.

ROCKS

Kernville series

Name and distribution

The name "Kernville series" was proposed by Miller (1931, p. 335) for metasedimentary rocks near Kernville. Miller and Webb (1940, p. 349, 350) subsequently extended their usage of the name to include the subordinate amount of metavolcanic rocks associated with the metasedimentary sequence in the Kernville quadrangle. Dibblee and Chesterman (1953, p. 13) use the name for metasedimentary rocks in the eastern part of the Breckenridge Mountain quadrangle.

Rocks of the Kernville series crop out in secs. 15, 22, and 27, T. 27 S., R. 32 E., and are the dominant rocks between Clear Creek and the eastern border of the area (pl. 1). Inclusions of schist as much as 7 feet wide and about 30 feet in outcrop length are enclosed in pegmatite near the Miracle mine (pl. 3). Some partly assimilated Kernville rocks may have been mapped as diorite and related rocks (pl. 1).

General description

The metamorphic rocks, which are undifferentiated in plate 1, are chiefly in roof pendants, which strike northward and dip from 45° W. to vertical (pl. 1). The beds where they are visible range from a few inches to about 2 feet in thickness, but in most places the bedding is obscured by metamorphic effects. Foliation is well developed and is generally parallel to the bedding. In places there are minor steep fractures, closely spaced, and on some of these there have been displacements of a foot or two. Neither the base nor the top of the Kernville series is exposed. Disregarding the effects, probably minor, of the many small drag folds and faults, the apparent thickness of the partial section of the Kernville series in the area is 3,700 feet. The contacts of Kernville rocks with intrusive rocks are commonly accordant and in places gradational for several tens of feet across their strike. Throughout the metamorphic areas the pegmatites, which commonly strike parallel with the bedding and schistosity, do not produce visible metamorphic changes. Weathering of the metamorphic rocks produces moderately smooth bare or grass-covered slopes, broken in places by knobs of pegmatite or resistant metamorphic rocks.

Lithology

The Kernville series consists mainly of mica schist and impure quartzite but includes a little calc-hornfels and marble. The quartzite and schist are commonly medium gray on fresh surfaces, and various shades of brown where weathered. The calc-hornfelses are tan, light brown, or buff, with alternating color bands; they weather medium or dark brown. The marble is bluish white to light gray, and weathers to a light-gray rock with pitted surfaces.

The metamorphic rocks were probably derived for the most part from muddy sediments deposited in a geosyncline, but they have been subjected to both regional and thermal metamorphism. They are commonly fine grained, but near intrusive contacts they are coarser grained and closely resemble some inclusions found in the granodiorite. Gradations between schist and quartzite are common. Most of the metamorphic rocks are in the amphibolite facies (Turner and Verhoogen, 1951, p. 446), but some of those near contacts with the Isabella granodiorite are in the pyroxene-hornfels facies (Turner and Verhoogen, 1951, p. 441).

Petrography

Schist

The schists contain essentially the same minerals as the impure quartzites. They are characterized by the strong parallelism of micas, and commonly by parallel or subparallel orientation of plagioclase and quartz. Some of the schists are locally gneissic, containing alternating biotite-rich and felsic bands, each about 0.5 mm thick. The average diameter of the quartz and plagioclase grains in the schist is 0.3 mm. The micas are commonly 0.5-0.6 mm by 0.1 mm, although at some places near contacts with the granodiorite they are more than 1 cm long.

The most abundant rock in the series is muscovite-biotite-quartz schist. The quartz, which generally is the most abundant mineral, is commonly strained and probably stretched, and locally contains minute mineral inclusions. Oligoclase is found in most of the schist; orthoclase is scarce or absent. Biotite, a widespread constituent, is in ragged grains with inclusions of accessory minerals. It is strongly pleochroic, with X = tan, Y = light brown, Z = reddish brown. Muscovite is moderately abundant, scarce, or absent. It occurs in ragged flakes that are commonly alined in parallel bands, and some isolated muscovite crystals or radial growths of muscovite lie across the foliation. A garnet (N = 1.825), probably almandine, was noted in one specimen of schist.

Accessory minerals include zircon, in crystals up to 0.05 mm long that form pleochroic halos in biotite; rarely sphene, in crystals less than 0.1 mm long; and opaque minerals, probably chiefly magnetite. Secondary minerals are chlorite, after biotite; clay minerals, after feldspars; and limonite and hematite, after opaque minerals.

Impure quartzite

The impure quartzite consists mainly of a granoblastic assemblage of quartz grains from 0.2 mm to 0.7 mm in diameter. Elongation of quartz crystals and subparallel arrangement of micas are evident in some specimens. The impure quartzites lack the well-developed foliation typical of schists.

The other minerals in the quartzite are biotite, oligoclase, and muscovite. Minor accessory minerals, which constitute about 2 or 3 percent of most of this quartzite, are magnetite(?), pyrite, zircon, and monazite(?). Secondary products include clay minerals, chlorite, calcite, epidote(?), and hematite.

Marble

The marble contains 80 to 99 percent of dolomite and calcite, and is chiefly granoblastic in texture. Stain tests indicate that the carbonate is prevailingly dolomite, although calcite is dominant in some specimens. Although some of the impure marble has discrete bands of other minerals 1 to 3 mm thick, the coarser marbles consist almost entirely of nearly equant grains of calcite or dolomite 2 to 4 mm in average diameter. Locally a porphyroblastic texture is formed by calcite or dolomite crystals 0.6 to 1 mm in maximum dimension in a groundmass of calcite or dolomite that has a grain size of about 0.1 mm.

The crystals mainly form an interlocking mosaic and are slightly elongated parallel to banding and bedding. Minute flecks of graphite are the only recognizable impurity in some of the purer marbles. The impure marbles contain a few scattered subrounded quartz grains, less than 10 percent each of diopside and forsterite, a little graphite, pyrite, hematite, and, uncommonly, minor aggregates of chalcedony, presumably remnants of chert. Secondary minerals found only in small amounts are limonite, sericite, and, locally along fractures, clay minerals. Some late-stage calcite forms veinlets that cut chalcedony and other minerals. Intergrowths of tremolite, in elongate crystals up to 3 cm long, and calcite occur in the marble adjacent to some faults.

Calc-hornfels

The typical calc-hornfels in the area is a crystalline diopside-grossularite rock with grains mostly 3 to 5 mm in diameter. Garnet is the most abundant mineral in many of these rocks. It is near the grossularite end of the grossularite-andradite series in composition, as indicated by comparing its specific gravity, 3.52, and its index of refraction, 1.752, with graphs in Winchell and Winchell (1951, p. 485). Much of the garnet occurs in large- to medium-sized dodecahedrons enclosing small grains of other minerals. Diopside, the second most abundant mineral, is near the diopside end of the diopside-hedenbergite series. Quartz is moderately abundant in anhedral grains about 2 mm in diameter. Sphene, the principal accessory, occurs in well-formed crystals less than 1 mm long, which are pleochroic from colorless to light brown. Calcite veinlets cut garnet and quartz. Clay minerals are sparsely distributed.

Some bands of buff to white calc-hornfels consist mainly of felty aggregate of wollastonite in elongate crystals 2 to 3 mm long.

Local small-scale additive metamorphism is evidenced by small zones of tactite. These contain small masses of scheelite and concentrations of iron minerals.

Age and correlation

The rocks of the Kernville series are older than the Cretaceous rocks which intrude them, but as no fossils have been found in them their lower age limit is unknown. Miller and Webb (1940, p. 352, 353), on the admittedly poor criteria of degree of metamorphism and lithologic similarity with certain rocks of the Calaveras group, of late Paleozoic age, tentatively regard the Kernville series as Paleozoic and probably Carboniferous.

The only nearby pre-Nevadan rocks that are accurately dated are those east of Mineral King, about 60 miles north of the Kern River uranium area, and the thick Garlock series in the El Paso Mountains, about 45 miles to the east. The metamorphic rocks of the Mineral King area have been described by Turner (1893, p. 451) and by Knopf and Thelan (1905, p. 242), and fossils from them were dated as "Late" Triassic by S. W. Muller (quoted in Durrell, 1940, p. 17). Parts of the Garlock series described by Dibblee (1952, p. 15) contain Permian fusulinids. It is quite possible that the Kernville series includes rocks of several geologic systems.

The Kernville series of the Kern River uranium area correlates in general with similar metamorphic rocks in the Kernville quadrangle (Miller and Webb, 1940, p. 352) and in the Breckenridge Mountain quadrangle (Dibblee and Chesterman, 1953, p. 16, 17).

Cretaceous intrusive rocks

The oldest intrusive rocks in the Kern River uranium area are diorites and related rocks, which have been largely assimilated by later magmas. Most of the area is occupied by the mass of intrusive rock known as the Isabella granodiorite. This mass forms one of the many large plutons that make up the Sierra Nevada composite batholith. The part of this mass that lies within the Kern River uranium area consists mainly of granodiorite, but it includes some moderate-sized bodies that range in composition from quartz monzonite to quartz diorite, and it contains many small mafic inclusions. Pegmatite and aplite dikes cut the plutonic and metasedimentary rocks.

Diorite and related rocks

Distribution and relations

Dioritic rocks crop out in several patches, the largest of them only a few hundred square feet in area. The only two areas of this unit that were mapped are in sec. 4, T. 27 S., R. 32 E., and in sec. 25, T. 27 S., R. 31 E. (pl. 1). These patches are believed to be partly assimilated remnants of gabbro(?) and diorite that were once much more widespread, and they may represent the oldest part of the Sierra Nevada batholith. They are closely associated with the more basic parts of the Isabella granodiorite and are cut by pegmatite dikes. They probably correlate with widespread but not abundant similar mafic rocks in the southern Sierra Nevada, which, according to Miller (1931, p. 343), range from olivine gabbro to diorite.

Petrography

The dioritic and gabbroic(?) remnants are brownish, strongly weathered, medium- to coarse-grained rocks characterized by abundant mafic minerals. Because of their scarcity, and the difficulty in obtaining fresh samples, they were not studied in detail. They probably range in composition from quartz diorite to gabbro, as do the more abundant gabbroic and dioritic rocks in nearby areas (Miller and Webb, 1940, p. 353, 354; Dibblee and Chesterman, 1953, p. 28-31).

The single specimen studied as a typical example is dark hornblende-biotite quartz diorite from the outcrop in sec. 4, T. 27 S., R. 32 E. This rock is hypautomorphic textured and consists of near-equant crystals 4 or 5 mm in average diameter. The dark minerals, which form about half the rock, are chiefly biotite with some hornblende. The light minerals are plagioclase (andesine) and quartz, and the accessories are allanite, apatite, zircon, and opaque minerals. The following elements were detected with an X-ray fluorescence spectrometer[/]:

Fe (strong), Mn (moderate), Ca (moderate), Th (trace), Zr (trace), Rb (trace).

[/] Elements with atomic numbers less than 20 (that of calcium) are undetected by the X-ray spectrometer techniques employed in this investigation, and consequently are not reported. The terms "strong", "moderate", "weak", and "trace", only roughly indicate relative abundance.

Isabella granodiorite

Name and distribution

The name "Isabella granodiorite" was given by Miller (1931, p. 344) to a composite intrusive body which occupies a large part of the Kernville quadrangle. This mass, according to Miller and Webb (1940, p. 358), was formed by several waves of intrusion that occurred within a relatively short space of time, and it includes rocks that range in composition from granite to diorite. It was named the Isabella granodiorite because the specimens first collected by Miller near the type locality at Isabella consisted of rock that he classed as granodiorite (though they were richer in potash feldspar than most granodiorite); and this term has become intrenched as a geologic name despite the fact that the most abundant rock in the mass was later found to be quartz monzonite (Miller and Webb, 1940, p. 343).

Because of these facts there is a certain awkwardness about the use of the term "Isabella granodiorite". This awkwardness is not very serious, however, in describing the geology of the Kern River uranium area, because in that area this geologic unit is in fact represented mainly by granodiorite. The difficulty will be evaded so far as possible, by using the term "the Isabella granodiorite" in writing of this geologic unit as a whole, and the word "granodiorite", not preceded by "Isabella" where it is appropriate for designating the kind of rock that is being described. In such a case, the word "Isabella" is superfluous, because there is no granodiorite in the area that does not form a part of the unit called "the Isabella granodiorite".

And moreover, since granodiorite is so much more abundant, in this area, than other granular intrusives, it seems permissible to call the rock that contains most of the ore deposits "granodiorite", even though the walls of some deposits may consist in part of quartz monzonite or quartz diorite that form part of the Isabella granodiorite.

The Isabella granodiorite underlies all but about one square mile of the Kern River uranium area. It intrudes rocks of the Kernville series, its contacts with which are generally sharp and mostly parallel to the bedding (fig. 3). It also cuts and partly assimilates diorite and related rocks, and it is cut in turn by pegmatite dikes.

Outcrops of the Isabella granodiorite range from poor to bold. Its degree of weathering depends largely on distance from fractures, from which the weathering commonly progresses outward. Blocks of fresh granodiorite, either partly or entirely surrounded by weathered granodiorite, are common, but where erosion penetrated deeply, as in the lower parts of the Kern River Canyon, the granodiorite is all fresh.

Petrography

The rock that constitutes most of the Isabella granodiorite mass is medium or coarse grained and commonly light gray. Hornblende-biotite granodiorite is the prevailing variety; only slightly less common are biotite granodiorite and hornblende-biotite quartz diorite. Hornblende-biotite quartz monzonite, biotite quartz monzonite, and biotite quartz diorite are sparsely represented. The granodiorite is typically equigranular, although biotite and hornblende are commonly elongated

Figure 3. Contact between Kernville series (Pks) and Isabella granodiorite (Kig) in road cut, sec. 15, T. 27 S., R. 32 E. Kp is pegmatite.

and alined along flow planes, and locally along lines of flow. Porphyritic facies occur in secs. 5 and 6, T. 27 S., R. 32 E., and in secs. 31 and 32, T. 26 S., R. 32 E. Granodiorite with a gneissic texture near contacts with rocks of the Kernville series crops out in secs. 22 and 27, T. 27 S., R. 32 E. The porphyritic rocks consist chiefly of coarse-grained feldspars and quartz, whose intercrystal spaces are occupied by small amounts of fine-grained mafic minerals. They weather deeply and are of diverse composition (fig. 4, nos. A-76, A-77, A-97, A-98).

The textures in the Isabella granodiorite are mostly medium grained and hypautomorphic; coarse-grained rocks and those with gneissic and porphyritic textures are merely local variations.

The compositions of specimens from the Isabella granodiorite are represented graphically in figures 4 and 5. These are ternary diagrams, based largely on the method of Johannsen (1939, p. 152, 153), and use modes determined by the point-count technique of Chayes (1949, p. 1-11). Locations on the diagram that are marked by specimen numbers denote Johannsen's point F, representing the quartz-orthoclase-plagioclase ratio. Johannsen's method was supplemented by one devised by C. D. Rinehart and D. C. Ross of the U. S. Geological Survey. This scheme uses a small triangle consisting of the upper part of the larger triangle. Points at the lower corners of the small triangle represent 45 percent hornblende and 45 percent biotite, and the apex represents 100 percent combined other minerals, so that a point representing a given specimen shows the percentages of biotite, of hornblende, and of the other minerals collectively, in that specimen. The percentage of other

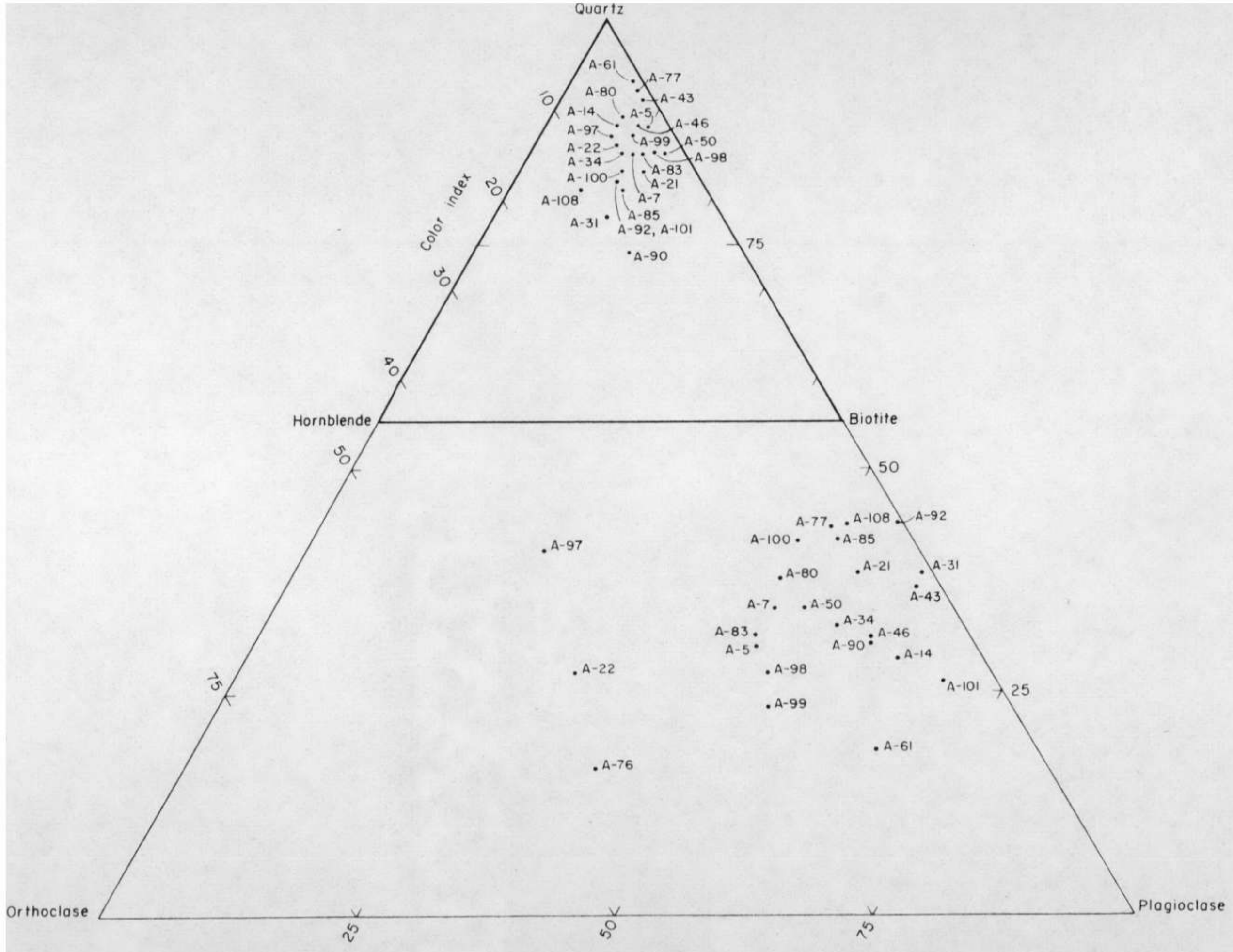


Figure 4. Compositions of specimens from the Isabella granodiorite mass in the Kern River uranium area, exclusive of Miracle and Kergon mine areas.

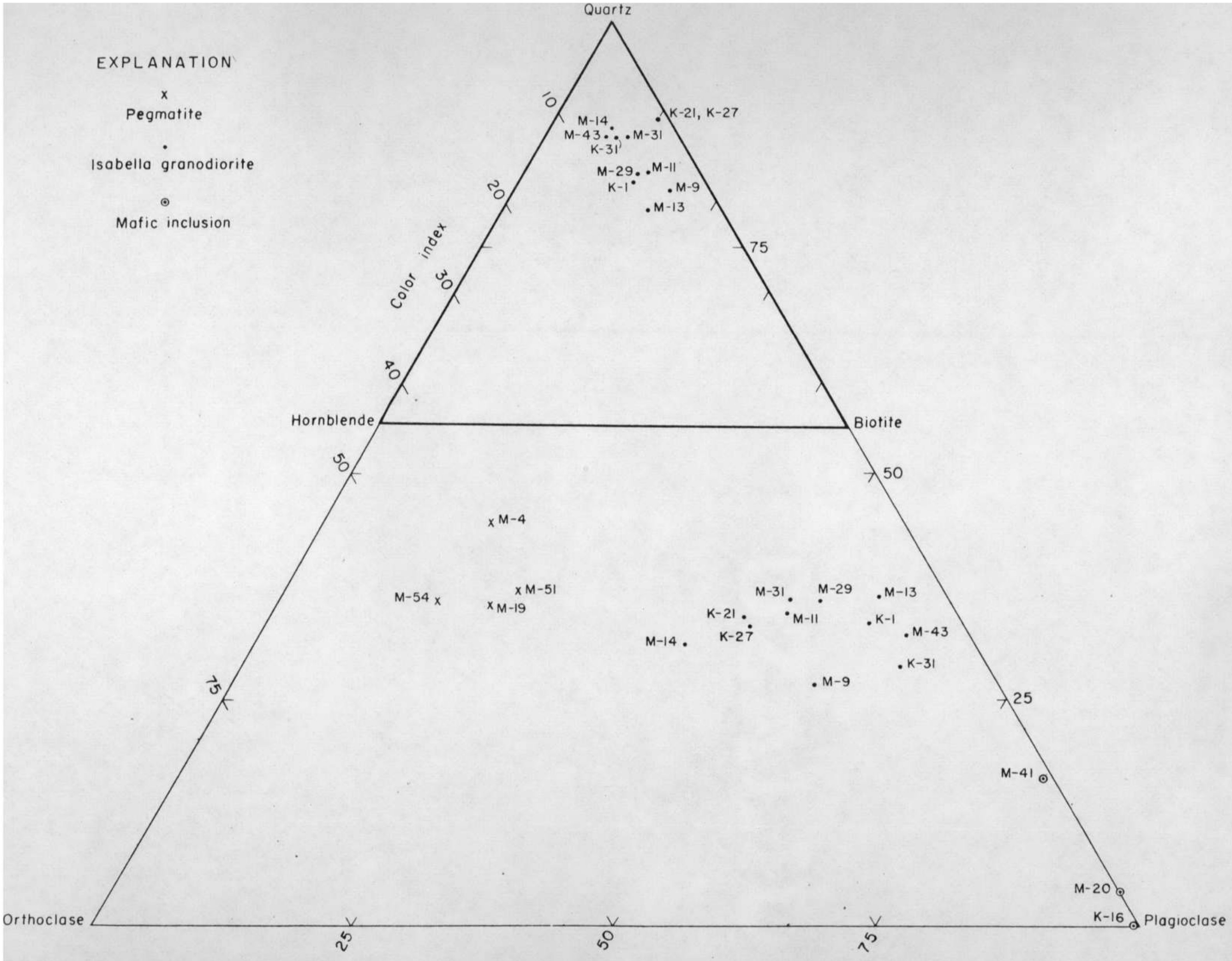


Figure 5. Compositions of rocks near the Miracle and Kergon mines. (Specimen numbers prefixed with M are from the Miracle mine, those prefixed with K are from the Kergon mine.)

minerals gives a close approximation of the color index, since the amount of mafic minerals other than biotite and hornblende is negligible. Specimen locations are shown in plates 1, 2, and 3, and in figure 16.

Typical quartz diorites are shown on figure 4 by nos. A-31, A-43, A-92, A-101, and A-108; nos. A-22, A-76, and A-97 are quartz monzonite; the remainder granodiorite.

The primary minerals in the Isabella granodiorite in the Kern River uranium area are listed in table 2. Most of these minerals are found in all of the rock species that constitute the Isabella granodiorite, but in different proportions.

Many secondary minerals occur in small amounts in the freshest granodiorite, and are abundant in strongly weathered granodiorite. The commonest are: clay minerals after feldspars; a pale-green variety of chlorite that probably is (-) penninite, chiefly after biotite; clinozoisite after plagioclase, epidote after biotite and hornblende; and, uncommonly, limonite after opaque minerals, sericite after feldspars, leucoxene probably after ilmenite, uralite after augite, and calcite after plagioclase.

The results of semiquantitative spectrographic analyses of granodiorite and a few related rocks from the Isabella mass are shown in table 3.

Table 2.--Primary minerals in the Isabella granodiorite, Kern River area.

Mineral	Abundance (percent)	Remarks
Plagioclase	20 to 61	Commonly in normally zoned subhedral crystals between An_{40} and An_{30}.
Potassium feldspar	1 to 40	Occurs chiefly in medium- or coarse-grained anhedral or subhedral masses. Abundant microperthite.
Quartz	15 to 40	In interstitial anhedral grains.
Biotite	6 to 15	Commonly in subhedral flakes. Pleochroism: X, tan or light yellowish brown; Y, light to medium brown; Z, reddish brown to dark brown.
Hornblende	<1 to 12	In prismatic crystals commonly 4 to 5 mm long. Pleochroism: X, light brown or greenish brown; Y, pale green, yellowish green, or greenish brown; Z, dark brown, green or greenish brown. More susceptible to weathering than the biotite.
Augite	<1	Identified in only one thin section.
Sphene	<1 to 1	Widespread minor accessory. Noted in every thin section.
Apatite	<1	Moderately abundant accessory in small euhedral crystals.
Opaque minerals	<1	Probably chiefly magnetite, subordinate ilmenite.
Zircon	<1	Moderately abundant accessory; in small euhedral crystals.
Xenotime	<1	Locally moderately abundant accessory; in small euhedral crystals.
Tourmaline	<1	Identified in only three thin sections. Probably a late-stage mineral. Pleochroism: O, bluish green, E, colorless.
Monazite	<1	Very uncommon.
Allanite(?)	<1	Very uncommon.

Table 3.--Results of semiquantitative spectrographic analyses of some rocks from the Kern River uranium area.[1] [2] (Locations of samples are shown in fig. 11 and pls. 1, 2, and 3.)

Quantity in percent

Number and name	Over 10	5-10	1-5	.5-1	.1-.5	.05-.1	.01-.05	.005-.01	.001-.005	.0005-.001	.0001-.0005	.00005-.0001
A-1, granodiorite (from near type locality at Isabella)	Si	Al	Na, Ca, Fe, K	Mg	Ti	Sr	Ba, Cu Li, Mn	B	Sc, Pb, Zr, Sn, V, Ga	Cr	--	Be
A-10, granodiorite	Si	Al	Na, Ca, Fe, K	Mg	Ti	Ba, Sr	Cu, Li	B	Sc, V, Y, Pb, Ga, Sn, Zr	Cr	Yb	Be
A-15, granodiorite	Si	Al	Na, Ca, K, Fe	Mg	Ti	Ba, Sr	B, Mn, Li, Cu	--	Zr, Sc, V, Pb, Sn, Ga	Cr	--	Be
A-32, quartz diorite	Si	Al	Fe, Ca, Na, K, Mg	--	Ti	Sr, Ba	Li, Mn	Cu, B	Zr, Sc, Ga, Pb, V, Y, Sr	Cr	Yb	Be
A-53, granodiorite	Si	Al	Fe, Ca, Na, K, Mg	--	Ti	Ba, Sr	Li, Mn	Cu, B	Zr, Pb, Cr, Y, Ga, V, Sc, Sn	--	Yb	Be
A-76, quartz monzonite	Si	Al	Na, Ca, K, Fe	--	Mg, Ba Ti	Sr	Cu, Li	Mn, B	Zr, Pb, Sc, Y, V, Sn, Ga	Cr	--	Be
A-89, granodiorite	Si	Al	Na, Ca, Fe, K, Mg	--	Ti	Sr, Ba	Mn, Li	Cu, B	Ni, Zr, V, Pb, Sn, Y, Ga, Cr, Sc	--	Yb	Be

[1] Mona Frank and Katherine E. Valentine, U. S. Geological Survey, analysts.

[2] Results of equivalent and chemical uranium analyses of these and other samples are shown in table 9, page 96.

Table 3.--Results of semiquantitative spectrographic analyses of some rocks from the Kern River uranium area.[1/2/] (Locations of samples are shown in fig. 11 and pls. 1, 2, and 3.)--Continued

Quantity in percent

Number and name	Over 10	5-10	1-5	.5-1	.1-.5	.05-.1	.01-.05	.005-.01	.001-.005	.0005-.001	.0001-.0005	.00005-.0001
K-2, pegmatite	Si	Al	K, Na, Ca	Fe	Mg	--	Ba	B, Sr, Ga, Mn	Zr, Y, Cu, V, Cr, Pb, Ti	--	Yb	
K-17, granodiorite	Al, Si	--	Fe, Ca K, Na	Mg	Ti	Ba	Sr	V, Zr, B, Ga	Cr, Y, Cu, Pb, Sc	Mo	Yb, Co	
M-28, granodiorite	Al, Si	--	Ca, Fe, K, Na	Mg	Ti	Ba, Sr	B, Mn	V, Ga	Cr, Cu, Y, La, Zr, Sc, Pb	Mo	Yb, Co	
M-30, mafic (inclusion)	Si	Al	Na, Ca, Fe, Mg	K	Ti	Sr	Mn, Li, B, Ba	Cu, Cr	Ni, Zr, Pb, V, Y, Sc, Sn, Ga	--	Yb	Be
M-35, granodiorite	Al, Si	--	Ca, Fe, K, Na	Mg	Ti	Ba, Sr	B, Mn	V, Cr, Ga, Zr	Y, Cu, La, Sc, Pb	Mo	Yb, Co	
M-41, granodiorite	Al, Si	--	K, Ca Fe, Na	Mg	Ti	Ba, Sr	B, Mn	V, Ga	Cr, Y, Zr, La, Cu, Sc, Pb	Mo	Yb, Co	
M-56, weathered granodiorite	Al, Si	--	Fe, Ca, K, Na	Mg	Ti	Ba, Sr	Mn, B	Zr, Cr, Ga, V	Cu, La, Y, Pb, Sc	Mo	Yb, Co	

Mafic inclusions

Sharply defined mafic inclusions, mostly less than a foot long, are abundant in the Isabella granodiorite in the southern half of the Kern River uranium area. The inclusions are discoidal or flatly ellipsoidal and lie oriented parallel to the flow planes of the enclosing rock. Their major and intermediate axes are generally from three to five times as long as the minor axis, but they range in shape from nearly spherical masses to long, narrow streaks. Most of them are from 6 to 12 inches in maximum and intermediate dimensions, and from 2 to 4 inches in smallest dimension. Where present the inclusions are generally more or less evenly distributed, but locally they occur in bunches or bands. Their distribution is related in a general way to the composition of the host rock: they are most abundant in quartz diorite, less abundant in granodiorite, and scarce in quartz monzonite.

The inclusions consist of diorite or quartz diorite. They are much more resistant to weathering than the coarser-grained diorite and gabbro, and in some outcrops they stand out in low relief. Where weathered they are dark brown to black.

The inclusions are composed mainly of anhedral crystals 0.5 to 2 mm in average diameter. Some of the inclusions are porphyritic, consisting of normally zoned plagioclase phenocrysts 5 to 7 mm long in a medium- or fine-grained groundmass. In some of them the mineral grains lie more or less parallel. The compositions of three inclusions are represented diagrammatically in figure 5, and further data on the primary minerals in the mafic inclusions are shown in table 4.

Table 4.--Primary minerals in the mafic inclusions.

Mineral	Abundance (in percent)	Comments
Plagioclase	47 to 54	Normally zoned in andesine-oligoclase range.
Quartz	<1 to 10	
Biotite	22 to 27	Strongly pleochroic: X = tan, Y = light brown, Z = dark reddish brown. Contains minute inclusions that form with pleochroic halos.
Hornblende	12 to 17	Generally poikilitic. Pleochroism: X = light greenish brown to tan, Y = light brown, Z = greenish brown.
Augite	<1 to 9	
Sphene	<1 to 1	
Opaque minerals	<1 to 1	Probably chiefly magnetite and ilmenite.
Apatite	<1	
Xenotime	<1	

Secondary minerals are pale-green chlorite and epidote after mafic minerals, clay minerals after plagioclase, colorless to light-brown uralite after augite, limonite after mafic and opaque minerals, leucoxene(?) after ilmenite, and hematite, locally with secondary quartz, after opaque minerals.

An X-ray fluorescence spectrometer examination of a mafic inclusion from the Miracle mine area revealed the following elements: Fe (strong), Mn (weak), Sr (trace), Ga (trace), Ti (trace), Ca (weak). (See footnote p. 27.) The results of a semiquantitative spectrographic analysis of a mafic inclusion are shown in table 3 (no. M-30).

Most of these inclusions probably represent fragments of once widespread basic plutonic rocks, but some may be reconstituted metamorphic rocks.

Age and correlation

Lead-alpha (Larsen method) age determinations on zircon concentrated from a 75-pound sample of Isabella granodiorite collected near the Miracle mine range from 85 to 96 million years. These absolute age determinations, which were made under the direction of H. W. Jaffe, U. S. Geological Survey, represent three different-sized fractions of zircon from the same concentrate. The average absolute age is 90 million years, nearly equivalent to the beginning of the Late Cretaceous epoch.

The Isabella granodiorite in the area here described is believed to represent a part of a vast batholithic mass, grading outward from a deep-seated central zone typified by the prevailing quartz monzonite of the Kernville quadrangle (Miller and Webb, 1940, p. 357) into contaminated border zones of more basic rocks. Miller (1931, p. 346) notes that the quartz monzonite and the typical Isabella granodiorite in the vicinity of (old) Isabella and (old) Kernville grade westward into quartz diorite. The part of the Isabella mass within the Kern River uranium area appears to be a single intrusive body.

Most of that part of the Isabella granodiorite which lies in the Kern River uranium area may represent contaminated marginal parts of the batholith. The various kinds of rock that it there consists of grade into one another, their differences apparently being due to their position in the batholith and their degree of contamination. Most of the rocks that exhibit considerable textural variations are at high altitudes, and probably they represent border facies formed near the roof of the batholith.

The Isabella granodiorite of the Kern River area correlates with similar rocks in the Kernville quadrangle. Biotite-quartz diorite and hornblende-biotite quartz diorite in the Breckenridge Mountain quadrangle, described by Dibblee and Chesterman (1953, p. 22-26), are probably contaminated border facies of the same rock.

Pegmatite

Distribution and thickness

Pegmatite dikes are abundant throughout the Kern River uranium area where they cut all the other crystalline rocks. Surface traces of most of the dikes are delineated on plate 1. The dikes generally form bold outcrops, and are particularly well exposed on the north walls of the Kern River canyon in secs. 17, 18, and 19, T. 27 S., R. 32 E.

Few of the pegmatite dikes are exposed for more than 100 or 200 feet, but a few of them are traceable for as much as 2 miles. They are mostly between 1 and 4 feet thick, but range in thickness from a few inches to about 200 feet. Their attitudes are diverse, but most of them strike northeast and dip gently northwest. In some places reversals in dip produce minor rolls and flexures. Branching dikes are uncommon. The large dike exposed low in the Kern River Canyon near the Kergon mine and northeast of it has a roughly elliptical outcrop extending along the Kern River (pls. 1, 2). The pegmatite dikes commonly cut across flow lines and flow planes in the Isabella granodiorite, but in the metamorphic rocks they generally strike parallel to the bedding and schistosity. Inclusions of metamorphic rocks of the Kernville series, as much as 30 feet long and 7 feet thick, occur in a few of the pegmatite dikes, notably the Miracle pegmatite dike and the thick dike in the northern part of the large roof pendant. Host rocks adjacent to the dikes show no metamorphic effects and their contacts are sharp. Figure 6 shows the lower contact of the Miracle pegmatite dike (pl. 3), one of the thickest in the area.

Petrography

In composition the pegmatite dikes mainly resemble granite, but some resemble quartz monzonite (fig. 5), as they range from extremely quartz-rich types through typical potash feldspar-rich granite and quartz monzonite pegmatites, to potash feldspar-rich types with little quartz. Most of them are unzoned and consist largely of medium-grained quartz and microcline with a little plagioclase and mica. A few of

Figure 6. Pegmatite (left) and granodiorite (right) -- contact strikes N. 55° W. and dips 50° NE. Miracle mine area (pod of coarse pegmatite indicated by arrow).

the thicker dikes are zoned, and contain one or more thin stringers or pods of very coarse grained potash feldspar or quartz or both intervening between layers of typical medium-grained pegmatitic material. Generally the very coarse grained minerals occupy the cores, but some of the thicker dikes contain several very coarse grained zones about a foot thick. A few dikes 4 to 6 feet thick are symmetrically zoned, with quartz cores, 6 to 12 inches thick, intermediate zones of graphic granite commonly about 4 to 6 inches thick, and border zones 1 to 2 feet thick of medium-grained potash feldspar mixed with a little quartz and plagioclase. Fine-grained, saccharoidal aplite makes up a small proportion of some of the pegmatites. Quartz-lined vugs are an uncommon feature. Small parts of a few pegmatite dikes are slightly radioactive.

The pegmatites are mainly medium- and coarse-grained rocks, but in some places they have very coarse pegmatitic textures, associated with graphic and vermicular intergrowths, while elsewhere they have fine-grained aplitic textures.

They are rich in potassium feldspar, mainly microcline, and in quartz. Most of the potassium feldspar crystals are between 1 and 5 mm in diameter, but microcline crystals as great as 10 cm in maximum diameter were noted in some of the very coarse grained zones. Aplitic parts of the dikes contain potash feldspar in the 0.5 to 2 mm size range.

The quartz content ranges from 10 to 90 percent. Most of the pegmatite dikes contain anhedral grains of quartz 2 to 5 mm in mean diameter, but some of the quartz grains in the cores of the zoned masses are as much as 10 cm across. In some dikes quartz forms graphic intergrowths with potassium feldspar or black tourmaline, and in places it is microscopically intergrown with potassium feldspar and plagioclase. Fine-grained quartz is the dominant constituent of the aplitic parts of the dikes.

Medium-grained intermediate oligoclase, An_{23-20}, makes up between 10 and 20 percent of most of the pegmatites, but plagioclase is apparently absent in the cores and graphic-textured intermediate zones of the zoned dikes.

Biotite in flakes a few millimeters long to plates and books about 5 cm long generally makes up from 1 to 4 percent of the medium-grained parts of the pegmatites. Its pleochroism is stronger than that of the biotite in the Isabella granodiorite: X light brown, Y brown, Z very dark brown. Some of the biotite is slightly radioactive, probably owing to minute inclusions of radioactive minerals.

Muscovite in fine- and medium-grained frayed subhedral crystals generally constitutes less than 1 percent of the pegmatites. A little black tourmaline occurs in spherical clots a few centimeters in diameter, in graphic intergrowths with quartz, or in irregular veinlets. Its pleochroism is: O bluish black, E colorless.

Other minor constituents are magnetite, garnet, sphene, apatite, euxenite, allanite, goethite(?), and xenotime(?). The magnetite forms more or less perfect crystals as much as 1 cm but commonly 1 or 2 mm long. Garnet forms reddish-brown dodecahedrons as much as 5 mm in diameter. The specific gravities of three garnet specimens determined on a Berman balance are 3.985, 3.990, and 4.000, and their indices of refraction as determined by oil immersion methods are between 1.81 and 1.82. By comparison with figure 378 of Winchell and Winchell (1951, p. 485), the garnets are in the pyrope-almandine (+ andradite) series. Sphene occurs in very small, weakly pleochroic crystals, some of them included in biotite. Apatite forms sparsely distributed euhedral crystals less than 0.4 mm long, commonly enclosed in potash feldspar. Euxenite occurs in a few pegmatite dikes in dark-gray to black crystals about 1 cm in diameter. It was identified by X-ray diffraction methods. Allanite and goethite(?) are widely scattered.

Secondary minerals in the pegmatites are: clay minerals, after feldspars; sericite, after feldspars; chlorite in minor amounts, after biotite; epidote, rare, after biotite; and limonite, after opaque minerals and also intermixed with very fine grained chlorite(?) on the peripheries of garnet crystals. In a few pegmatites fracture walls are coated with colorless botryoidal opal that fluoresces bright yellow green.

The results of a semiquantitative spectrographic analysis of a pegmatite sample from the Kergon mine are shown in table 3 (no. K-2). The following elements were found in a pegmatite sample from the Miracle mine area with an X-ray fluorescence spectrometer: Fe (strong), Ca (moderate), Zr (trace), Y (trace), Sr (trace), Rb (trace).

Age and correlation

The pegmatite dikes were emplaced at a late stage in the magmatic activity of the Sierra Nevada batholith. They are probably Cretaceous in age, like the Isabella granodiorite (p. 40).

Pegmatites similar to those in the Kern River uranium area are widespread and abundant throughout the southern Sierra Nevada. Miller and Webb (1940, p. 351) briefly describe the pegmatites in the Kernville quadrangle. Dibblee and Chesterman (1953, p. 32) discuss pegmatites in the Breckenridge Mountain quadrangle that are like those in the Kern River uranium area. Minor radioactivity anomalies have been found in many pegmatites in the southern Sierra Nevada (W. A. Bowes, U. S. Atomic Energy Commission, oral communication, 1955).

Quaternary sedimentary rocks

River terrace deposits

Unmapped mantles of unconsolidated river terrace deposits, two or three acres in maximum area, locally overlie the intrusive rocks in the Kern River Canyon near the eastern boundary of the mapped area (sec. 10, T. 27 S., R. 32 E.). The deposits consist of well-rounded pebbles, cobbles, and boulders of granitic and metamorphic rocks. They are 10 to 15 feet in maximum thickness, and their base is about 15 feet higher than the river's present average water level. The river terrace deposits are probably Recent in age.

STRUCTURE

The dominant structural features in this area are prominent, steep-dipping secondary fractures, which cut all the crystalline rocks, and well-developed planar structures. The secondary fractures are not related to shrinkage accompanying the solidification of the magma but have resulted from regional stress. The fractures are joints and minor faults; slips ranging from a few inches to about 12 feet are locally evident. The features shown as fissures on plate 1 are believed to be steep-dipping fractures. They are conspicuous on aerial photographs but commonly unexposed or poorly discernible in the field. North-south compressional forces have probably caused small-scale movement on many fractures. The fractures are roughly divisible into four sets, all of which dip steeply. The stronger sets trend N. 15° to 40° W. and N. 60° E. to E. and the weaker sets N. 15° to 35° E. and N. 50° to 80° W. This diversity in attitudes probably resulted from rotations in the direction of regional compression, and the weaker fracture sets may be of the second order (McKinstry, 1953, p. 401-414). An alternative but closely similar interpretation is that the four sets represent two conjugate fracture systems, one set having formed later than the other, after the reorientation of compressive forces.

In places it is difficult to distinguish between joints and faults. Many fractures have iron-stained and slickensided walls, yet few exhibit offsets of more than a few inches. It is likely that major adjustments in response to regional forces were made on nearby faults outside the Kern River uranium area such as those of the Kern Canyon fault zone, and that only local minor movements occurred within that area.

Faults

No major faults were found in the Kern River uranium area. Minor movements on local segments of the four fracture sets produced a few definite faults, and the fissures shown in plate 1 probably include numerous minor faults.

The principal faults are right lateral, strike N. 20° to 40° W., and dip steeply. They are exemplified by the Miracle shear zone (pl. 3). Minor steep faults strike N. 60° E. to E. and N. 15° to 30° E. Where observed, the faults of the former group are left lateral, probably conjugate with the northwest-striking faults. The direction of movement on the faults of the latter group was not ascertained, but slickensides and grooves indicate a strong strike-slip component.

Miracle shear zone

The Miracle shear zone, along which the workings of the Miracle uranium mine extend, is traceable for about 1,300 feet in the granodiorite and pegmatite (pl. 3). The shear zone is mainly composed of many nearly parallel fractures. It passes into a joint to the north, and to the south it splits into numerous weak fractures. The shear zone generally strikes N. 33° W., and its constituent fractures commonly dip from 80° NE to 80° SW. The thickness of the shear zone reaches a maximum of about 6 feet, but in most places it ranges from a few inches to about 2 feet (fig. 11). Displacement along this fault, as determined by offset pegmatite dikes in the Miracle mine, is as great as 12 feet and right-lateral. The slickensides on its walls are nearly horizontal or plunge gently northwest. Many of the fractures contain gouge and coatings of secondary iron oxides and locally autunite. The strongest fractures are mostly along the southwest margin of the shear zone.

Kergon shear zone

The Kergon shear zone is exposed for a strike length of about 230 feet (pl. 2) and attains thicknesses of 15 feet (figs. 8, 9, 10). It commonly strikes N. 26° E. and dips 50° to 65° SE. There are many diversely trending shear surfaces in the highly altered rock and gouge between the major fractures of the shear zone. Other sets of fractures apparently branch off from, or are cut by, the Kergon shear zone (fig. 8). Many slickensides are superposed on gouge; some of these are near horizontal, and others plunge as much as 30° NE. Bleached argillic alteration products and iron and molybdenum stains locally pervade the shear zone.

Other faults

Faults representing each of the four sets of fractures are discernible. The dominant faults are nearly vertical and strike N. 20° to 40° W. They are exemplified by the fault at the lower no. 11 cut in the Miracle mine area (pl. 3, fig 14), whose probable extension is traceable for at least 2,500 feet on the north side of the Kern River, and by the fault in nos. 9 and 10 cuts, of that area (pl. 3, fig. 14). The major fissures trend N. 20° to 40° W., and many are in part faults.

Steeply dipping faults that strike N. 60° E. to E. and fissures with similar attitudes are moderately abundant. Steep faults dipping southeastward and striking N. 15° to 30° E., probably relate to the Kergon shear zone, and fissures indicative of similar fractures, are widespread. Steep faults trending N. 50° to 80° W. are less common.

Joints

The most numerous fractures are secondary joints that cut all the crystalline rocks (pls. 1, 2, 3). Most of them are steep, and fall within two sets that form a conjugate system. One major set strikes N. 15° to 45° W., and the other N. 60° E. to E. The other steep joints are generally parallel to one of the lesser sets of fractures. The flatter joints, which are probably due to sheeting, range in dip from nearly horizontal to about 25°; they are best exposed along the steep sides of Kern River Canyon. The joints are generally spaced at intervals of between 20 and 40 feet, but in places they are more closely spaced.

Most of the joints are tight, clean fractures. Some joint surfaces, however, are coated with limonite and other secondary minerals, and a few joints are open and partly filled with regolithic debris.

Most of the numerous gently dipping pegmatite dikes in the central part of the area (pl. 1) are believed to occupy primary flat cross joints, and a few were emplaced in primary diagonal joints and primary longitudinal joints (Balk, 1937, p. 34).

Planar and linear structures in the Isabella granodiorite

Most of the Isabella granodiorite exhibits well-developed planar structure by the alinement of mafic inclusions along flow planes. Planar structures are also represented by schlieren and schlieren-like bands, which consist mostly of mafic minerals but in places consist of felsic minerals (fig. 7).

The planar structures commonly strike between N. 70° E. and E., or between N. 70° W. and W.--a reflection of nearly north-south compression. Steep southerly to vertical dips prevail. Aberrant attitudes are found adjacent to the roof pendant of rocks of the Kernville series and in the southwest part of the area. In these places, flow lines became adjusted to pre-existing structures in older rocks, for attitudes of the planar structures are nearly parallel to foliation in the metamorphic rocks and to the intrusive contacts.

Lineations due to the orientation of elongate minerals, chiefly hornblende, occur locally but were not studied in detail. Where observed, they are alined in flow planes and plunge steeply east or west.

Structures in the Kernville series

Structures other than the faults and fissures shown on plate 1 are common in the Kernville series but were not studied in detail. The bedding strikes nearly north and dips 45° W. to vertical. Bedding and foliation, where observed, are parallel. The foliation is chiefly schistosity due to parallelism of mica flakes in schist.

Figure 7. Planar structure in Isabella granodiorite exemplified by stretched mafic inclusions and leucocratic schlieren. Miracle mine area.

The dominant fractures in the metamorphic rocks strike nearly east and are nearly vertical. Other fractures, closely spaced and diverse in attitude, are associated with minor folds; these are probably fracture or slip cleavage. Minor drag folds and plications are abundant in the metamorphic rocks, generally trending northward and plunging steeply. Marble beds involved in the folding generally thicken and thin.

GEOLOGIC HISTORY

The earliest event recorded in the Kern River uranium area was the deposition of the sediments of the Kernville series, probably during late Paleozoic and early Mesozoic time. The thick, largely pelitic, sedimentary sequence was probably deposited in a miogeosyncline trending northwest.

The next major geologic event was the Nevadan orogeny in Cretaceous time, which entailed uplift of the thick sedimentary pile, general east-west compression, and local faulting. Metamorphism commenced with deep infolding of the sediments and continued in various degrees throughout the period of batholithic intrusion probably into Late Cretaceous time. Minor dioritic bodies crystallized near the margins of the batholith; these were followed by, and locally engulfed in, the prevailing granodiorite-quartz monzonite magma, possibly in successive surges. Pegmatite dikes were emplaced in the waning stages of igneous activity but prior to the deposition of gold-quartz veins. By the close of the Nevadan orogeny, the area had presumably been elevated to great heights.

Post-Cretaceous geologic history is poorly recorded in the area. Dibblee and Chesterman (1953, p. 52, 53), as a result of their studies in the Breckenridge Mountain quadrangle, believe that erosion prevailed during Eocene time, that diastrophism re-elevated the southern Sierra Nevada into rugged mountains during the Oligocene, that the Miocene was largely a time of erosion, that deposition and minor diastrophism took place in the Pliocene, and that the Cascadian orogeny dominated Pleistocene geologic activity and culminated in the uplift of the Sierra Nevada, tilting, and the development of many faults in late Pleistocene time.

The age of the secondary fractures and the uranium deposits in them in the Kern River area is conjectural. Probably most of the secondary fractures formed early in the Cascadian orogeny (early Pleistocene), at the time when Dibblee and Chesterman (1953, p. 53) believe most of the major faults of the southern Sierra Nevada originated. The fact that a few of the fractures in the area are quartz bearing and contain minor gold deposits supposedly associated with the Nevadan orogeny is somewhat against this idea, but the few fractures involved are possibly remnants of an older set. Most, if not all, of the uranium deposition probably took place in the Quaternary period.

Erosion prevailed during the Recent epoch and carved the steep-walled Kern River Canyon. Minor Recent deposition is indicated by stream gravels in the eastern part of the area.

ECONOMIC GEOLOGY

Mining activity in the Kern River uranium area is divisible into three phases: (1) gold prospecting, probably resulting from successful mining in the nearby Cove, Keyes, and Clear Creek (Havilah) districts between 1850 and 1880; (2) tungsten prospecting, which began during World War I and was stimulated by the demand for tungsten during World War II; and (3) uranium prospecting, impelled by the discovery of the Miracle mine deposit in January 1954. Despite considerable prospecting, attested by numerous shallow exploratory workings, the area has yielded only small quantities of ore. Parts of the Clear Creek, Keyes, Greenhorn Mountain, and Pioneer mining districts are in the area.

The uranium deposits, with a few exceptions, are localized in regional secondary fractures in the Isabella granodiorite. Tungsten occurs both in quartz veins and in tactite in rocks of the Kernville series in the southeastern part of the area. Gold, exclusive of placer deposits, is found chiefly in quartz pods and veins cutting the more leucocratic parts of the Isabella granodiorite in the northern part of the area. The tungsten and gold deposits were little studied during the present investigation, and the brief descriptions included here are largely abstracted from reports of the California State Division of Mines.

URANIUM DEPOSITS

Uranium deposits are widespread in the area but are most abundant in the central part. Except for minor deposits in pegmatite, the uranium deposits are epigenetic and were formed where uranium minerals, principally autunite, coat fracture surfaces, locally form small pods and veinlets, or are spottily disseminated in the granodiorite wall rock. The richest deposits found so far are associated with braids of faults that constitute shear zones. Limonite and clay minerals, indicative of weak to locally intense argillic alteration, generally accompany the uranium minerals, but common gangue minerals are notably scarce in many of the uranium occurrences in this area. Fractures in each of the four sets found in the area locally contain some autunite, but most of the known uranium deposits are in steep fractures trending N. 20° to 40° W., as shown by the plots of uranium prospects and radioactivity anomalies in plates 1, 2, and 3. Uranium minerals are intermittently distributed along the favorable fractures, but only in small areas are they sufficiently concentrated to form ore; local accumulations of uranium minerals along the fractures are generally separated by wide gaps of barren or lean material.

Local minor anomalous radioactivity in some pegmatites probably indicates small quantities of sparsely disseminated syngenetic complex uranium-thorium minerals. Euxenite, allanite, and questionably xenotime have been found in a few of the pegmatite dikes, and it is probable that other uranium-bearing minerals are present but were not detected.

Many uranium claims have been staked in the area, but on most of them no work other than that required for location has been done. The only underground workings are at the Kergon and Miracle mines, and the only uranium shipments from the area were from these mines. Most of the prospects are shown in plates 1, 2, and 3, but some, particularly those consisting of shallow bulldozed cuts at sites lacking anomalous radioactivity, are not plotted on the maps. Most of the workings are shallow pits, trenches, and open cuts along weakly radioactive fractures cutting the Isabella granodiorite. A smaller number of minor surface workings are in pegmatites, and some are in non-radioactive, apparently barren host rock. Mining development has been hampered by overlapping claims and ensuing legal entanglements, but more particularly by the lack of ore. Early in 1956 there was little mining activity in the area. Most of the uranium discoveries, including the first ones at the Miracle mine, were made by amateur prospectors, and from time to time the area has been invaded by hordes of weekend prospectors.

Kergon mine

Location

The Kergon mine is in sec. 20, T. 27 S., R. 32 E., Mount Diablo Base and Meridian, on the steep south wall of Kern River Canyon (pl. 1, fig. 1). The mine area is at altitudes between 2,200 and 2,700 feet, and is readily accessible from State Highway 178, which cuts across it.

History and production

The Kergon claims were located by J. Kerns and W. Waggoner of Taft, California, in May 1954, and shortly thereafter they were sold to the Great Lakes Oil and Chemical Company. During the summer of 1954 the company enlarged the original discovery cut ("Charley's cut") to a depth of 10 feet, excavated "A" cut, and drove the main adit under "A" cut (pl. 2) (Walker, Lovering, and Stephens, 1956, p. 30).

Subsequent work, consisting chiefly of extending the main underground workings, was carried on intermittently until January 1956, when the property was shut down.

Production[/] consists of two shipments made to the Vitro Uranium Co. at Salt Lake City during the summer and fall of 1955. The first shipment consisted of 50.7 tons that contained 0.14 percent uranium. The second shipment, chiefly "black ore" from "C" level, contained about 50 tons that averaged 0.18 percent uranium.

Workings

The underground workings, which are accessible through the main adit (pl. 2), comprise three levels, an interconnecting winze, a subsidiary winze, and minor stopes (fig. 8). The "A" or adit level, at an altitude of 2,435 feet, consists of a crosscut adit 40 feet long and about 70 feet of drifts. The "B" level workings, at an altitude of 2,407 feet, consist of short drifts, totalling about 30 feet, north and south of the main winze. The "C" level, at an altitude of 2,355 feet, consists of about 195 feet of drifts, 25 feet of crosscuts, and local small stopes. The main winze, which connects all three levels, is 88 feet in slope length and has an average inclination of about 67°. A subsidiary winze extends 32 feet northeastward from near the head of the main winze on "A" level, at an inclination of 28°.

[/] Permission to publish production figures granted by mine owners, the Great Lakes Oil and Chemical Company.

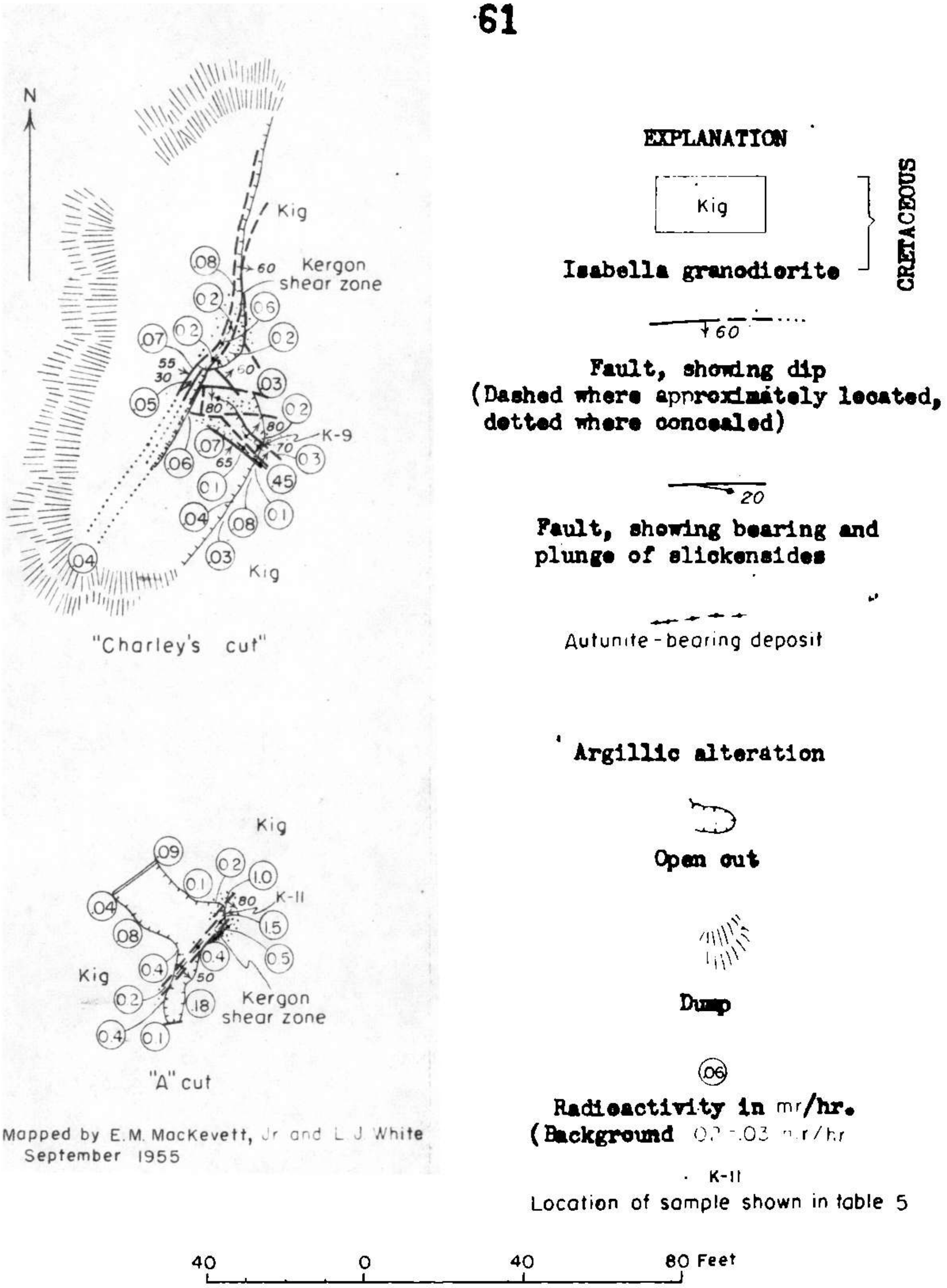
The principal surface workings are "A" cut and "Charley's cut" (pl. 2, fig. 9). "A" cut is a trench, about 25 feet long, 5 to 6 feet deep, commonly 10 to 12 feet wide that extends southerly into a 20-foot long, 4-foot wide trench.

"Charley's cut" actually consists of a cut, a shallow pit, and a trench. The cut, which extends northeastward, is about 90 feet long and 2 to 12 feet deep. The pit, whose long side parallels the cut, is about 12 feet long, 6 feet wide, and 2 to 3 feet deep. The trench, which extends northwest, is about 20 feet long, 4 to 8 feet wide, and 4 to 6 feet deep.

Many other cuts and trenches on the property are in only slightly radioactive localities and are not described. Many narrow trenches a foot or two deep and as much as 150 feet long were dug by hand to test for radioactivity; these are shown in plate 2 and figure 10.

Geology of the Kergon area

The prevalent rocks in the mine area are the Isabella granodiorite, with its mafic inclusions, and pegmatite dikes (pl. 2). All of the Isabella granodiorite specimens from the Kergon mine area that were studied in thin sections have the composition of granodiorite (fig. 5). The one sample of fresh granodiorite from the Kergon mine area that was analyzed (table 9, no. K-17) contained the abnormal amount of 30 ppm uranium. The mafic inclusions and pegmatite dikes are typical of the inclusions and dikes throughout the entire area.



Mapped by E.M. MacKevett, Jr and L.J. White
September 1955

EXPLANATION

Kig

Isabella granodiorite

CRETACEOUS

60

Fault, showing dip
(Dashed where approximately located, dotted where concealed)

20

Fault, showing bearing and plunge of slickensides

Autunite-bearing deposit

Argillic alteration

Open cut

Dump

06

Radioactivity in mr**/hr.**
(Background 02-.03 mr/hr

K-11
Location of sample shown in table 5

Figure 9. Geologic map of "A" cut and "Charley's cut", Kergon mine

The principal faulting in the mine area has taken place on the Kergon shear zone, which strikes N. 20° E. and dips 50° to 65° SE pl. 2). There are also some steep faults in the area that strike N. 55°-80° E. and N. 30°-60° W., but these cannot generally be traced for more than 200 feet. The faults are mainly single iron-stained and slickensided breaks, probably formed by local movement on the regional fracture sets.

Closely spaced multiple fractures and shears are evident in the shear zone exposed in "Charley's cut". This shear zone is 5 feet wide, strikes N. 35° to 45° W., and dips 65° to 80° NE. It apparently curves into and is truncated by the Kergon shear zone (fig. 8). Elements of the northwest-striking shear zone are represented by small cross fractures within the Kergon shear zone. Still weaker fractures generally strike within 20° of east and dip about 45° N. Few displacements of pegmatite dikes have been seen. At a few localities faults that strike N. 55° to 80° E. offset the dikes, producing left-lateral displacements of 1 or 2 feet.

The dominant sets of joint are nearly vertical and strike N. 20° to 40° W. and N. 60° to 80° E. Planar structures, rendered conspicuous by mafic inclusions alined in the Isabella granodiorite, strike within the 40° sector bisected by due east, and dip 60° S. to vertical. The few lineations observed in the Isabella granodiorite are nearly vertical.

Uranium deposits

Uranium minerals are indicated in the mine area by many weak radioactivity anomalies (pl. 2, figs. 9 and 10), but the only places where they appear to be concentrated are in the Kergon shear zone and the northeast-dipping shear zone exposed in "Charley's cut". Most of these anomalies are probably due to secondary uranium minerals dispersed along fractures.

Deposits in the Kergon shear zone.--The uranium deposits in the Kergon shear zone are of two types--"black ore" and "autunite-rich ore". The "black ore", which contains sooty pitchblende and secondary molybdenum minerals, forms pods and minor disseminations. Some of the "autunite-rich ore" forms irregular halos around pods of the "black ore", and some of it forms fracture coatings and minor veinlets, or is disseminated in altered granodiorite and the gouge of the shear zone. In places it encloses flecks of a dark uranium mineral. The "autunite-rich ore" is dominant near the surface and was probably derived for the most part from the "black ore".

The uranium deposits are irregularly distributed along the Kergon shear zone, and are separated by considerable barren or submarginal material. The shear zone is intermittently uranium bearing for at least 200 feet along its strike at the surface. Radioactivity anomalies in test trenches south of "Charley's cut" indicate that a weak southward extension of the Kergon shear zone contains sparsely distributed uranium minerals for at least another 150 feet (fig. 10).

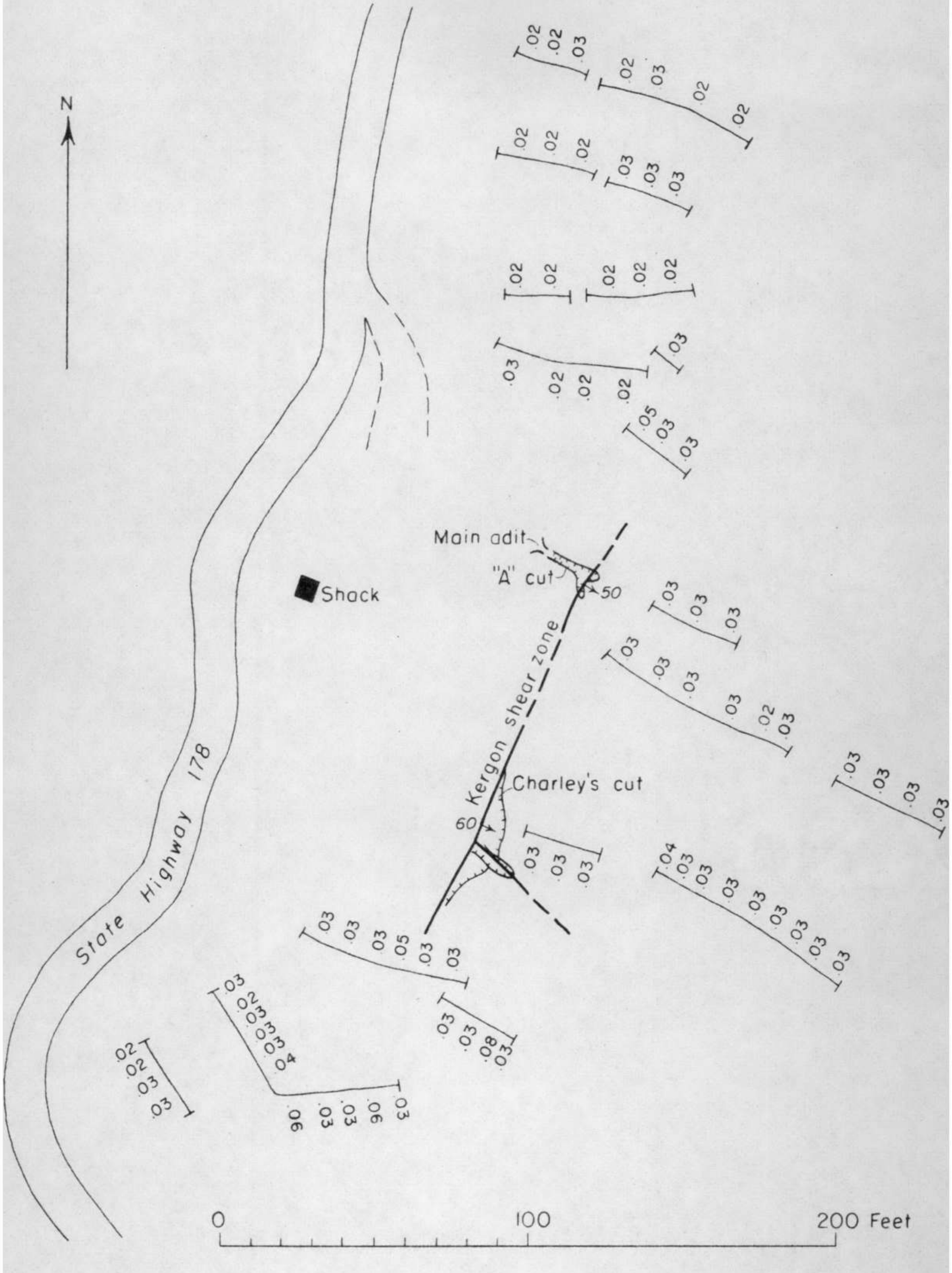


Figure 10. Map showing radioactivity in mr/hr in test trenches at the Kergon Mine (Background 0.02 to 0.025 mr/hr)

Surface exposures of autunite-rich deposits along the Kergon shear zone can be seen in "Charley's cut"[/] and "A" cut (fig. 9).

In "Charley's cut" the shear zone is from 1 to 5 feet thick, and contains concentrations of autunite for about 20 feet along the strike near its junction with a northwest-striking shear zone. The autunite-rich body is about a foot thick, and most of the autunite was localized along iron-stained fractures that form part of the Kergon shear zone, but some was deposited in minor iron-stained northwest-striking fractures where they cross the Kergon shear zone. A little autunite is disseminated, also, in gouge and argillized granodiorite wall rock. Radioactivity in the deposit ranges from 0.08 to 0.60 mr/hr against a background rate between 0.02 and 0.03 mr/hr (fig. 9). Grab samples from the deposit collected by U. S. Atomic Energy Commission geologists contained as much as 0.16 percent uranium (Walker, Lovering, and Stephens, 1956, p. 30).

An autunite-rich zone 1 to 3 feet thick is exposed in "A" cut for a strike length of about 20 feet (fig. 9). The autunite is almost confined to the Kergon shear zone, and is chiefly associated with the predominant northeast-trending shears and minor cross fractures. In places a little autunite is disseminated in altered granodiorite wall rock. Radioactivity in the deposit ranges from 0.09 to 1.5 mr/hr against a mr/hr background of 0.02 to 0.03. According to U. S. Atomic Energy Commission data, chip samples and dump material from "A" cut assayed around 0.17 percent uranium.

[/] The deposit associated with the northwest-trending shear in "Charley's cut" is described under "Other deposits".

Discontinuous uranium deposits, generally less than a foot thick, extend along the Kergon shear zone on "A" level over a length of about 47 feet (fig. 8). Very thin coatings of uranium minerals line some of the other fractures cut by "A" level. Most of these uraniferous fractures probably belong to the Kergon shear zone, but some of those on "A" level are outside the main shear zone. Elements of other fracture sets do not generally contain uranium here. Autunite-bearing deposits prevail, and are mainly confined to intensely sheared parts of the Kergon shear zone. The radioactivity ranges from 0.20 to 1.0 mr/hr, and the background radioactivity is about 0.04 mr/hr. U. S. Atomic Energy Commission assays of samples 1 to 6 feet long from the Kergon shear zone show 0.13 to 0.26 percent uranium. A sample 1 foot long from a high-grade uraniferous concentration near the face of the southwest-trending drift assayed 0.43 percent uranium_/. Six tons of ore sorted from the drift north of the main winze assayed 0.20 percent uranium, and about 50 tons sorted from the crosscut probably contains about 0.08 percent uranium.

On "B" level, north of the main winze, there is an autunite-bearing deposit about 2 feet thick and 12 feet long (fig. 8) that contains small pockets of "black ore". The deposit appears to be a lens that pinches out a few feet above and below the level. It may have been formed between concavities in the walls that were brought opposite each other by faulting, or at places where the zone of brecciation was widened at the intersection

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_/ Assay data unless otherwise noted are from U. S. Atomic Energy Commission sources.

of the Kergon shear zone with strong fissures trending N. 60° E. The autunite occurs mainly in surface coatings and veinlets, principally where minor shears abound in the shear zone. Radioactivity in the deposit ranges from 0.2 to 2.2 mr/hr; the background radioactivity underground is about 0.04 mr/hr. Channel samples representing lengths between 1 and 7 feet assayed 0.05 to 0.35 percent uranium. There are lean deposits of uranium minerals in the southern part of the level.

On "C" level "black ore", in more or less discrete deposits along the Kergon shear zone, preponderates (fig. 8). North of the winze small deposits of this type are spottily distributed along fissures in the shear zone. "Black ore", irregularly fringed with "autunite-rich ore" and stained with secondary iron and molybdenum minerals, occurs intermittently along the drift for about 25 feet south of the foot of the main winze in masses 2 to 5 feet thick. The uranium minerals are found chiefly along diversely trending subsidiary shears between the major shears. Nearly horizontal slickensides are common on surfaces of the major shears. The radioactivity of the deposit was between 0.50 and 1.5 mr/hr; the lowest background count in the drift was 0.05 mr/hr. Samples 2 to 5 feet long from this deposit contained between 0.05 and 0.24 percent uranium.

The ore body exposed near the south end of "C" level is about 30 feet long and up to 3 feet thick, but pinches out in small stopes a few feet above and below the level. The deposit lies between two major fractures of the Kergon shear zone, in gouge-rich material cut by numerous variously trending subsidiary shears. There are nearly horizontal slickensides on the walls of the main shear zone. "Black ore" constitutes the bulk of the deposit. It grades laterally into a thin autunite-rich aureole which merges into a region of intense argillic alteration. Much of the "black ore" appears to be a pod deposited in an open space within the shear zone. Most of the autunite forms films in subordinate flat-lying fractures. Radioactivity ranges from 0.30 to 4.0 mr/hr, and background near the southern face of the drift is 0.05 mr/hr. Company and U. S. Atomic Energy Commission assays as well as the second shipment indicate that this ore body averages about 0.17 percent uranium. Intersections, exposed at the south end of the drift, between the northwest-striking shear zone (exposed in "Charley's cut") and the northeast-striking Kergon shear zone are apparently barren of uranium minerals.

The main winze goes through scattered uranium deposits along the Kergon shear zone (fig. 8). Chief among these are a deposit extending a few feet below "A" level, the "B" level ore body, and a deposit near the foot of the winze on "C" level. In general, "autunite-rich ore" is dominant above "B" level, and "black ore" below.

Other deposits.--The only known significant uranium deposit in the mine area that is not controlled by the northeast-trending Kergon shear zone is localized in the northwest-trending shear zone exposed in "Charley's cut" (fig. 9), which contains the first uranium deposit to be discovered at the Kergon mine. This deposit, which is rich in autunite, is erratically distributed through a strike length of about 15 feet and a thickness of 5 feet, and is accompanied by white clay minerals. Its maximum radioactivity is 0.45 mr/hr, against a background of 0.03 mr/hr. A chemical analysis of a 0.6-foot long sample revealed 0.16 percent uranium.

Mineralogy and composition.--The friable "black ores" are very fine grained intimate mixtures of various minerals, pervaded by the blue and black stains of secondary molybdenum minerals.

The mineral constituents of the black ores, most of them originally identified by U. S. Atomic Energy Commission personnel and also subsequently during the present investigation, are sooty pitchblende, the secondary molybdenum minerals ilsemannite and jordisite, fluorite, clay minerals, gypsum, and limonite(?). The "black ore" grades outward into the "autunite-rich" type. Most of the uranium is contained in dark-gray powdery masses of sooty pitchblende. Some of the masses have a blue-black color imparted by ilsemannite and jordisite, the latter probably subordinate to the former. Fluorite occurs in small crystals 1 to 2 mm across. The prevailing clay mineral is montmorillonite. The ilsemannite-rich "black ore" is locally coated with gypsum, which forms small colorless acicular crystals, partly in divergent aggregates, and partly in fine shreds.

A sample of "black ore" from a pocket in the main winze near "B" level contained 1.08 percent U_3O_8, 1.1 percent CaF_2, and 1.84 percent Mo (Walker, Lovering, and Stephens, 1956, p. 30). The compositions of two "black ore" samples from "C" level as determined by X-ray fluorescence spectrometer examinations are shown in table 5, nos. C-1 and C-2.

Table 5.--Results of X-ray fluorescence spectrometer analyses of some uranium-bearing samples from the Kergon Mine. (See footnote, p. 27.)

Number and location	Relative quantity in sample Strong	Moderate	Weak	Trace
K-11 Autunite-rich sample from "A" cut	Fe	U	As	Sr, Cu, Mn, V
K-30_A Autunite-rich sample from "B" level ore body	Fe, U		Sr, As	Cu
C-1 Black ore, "C" level	Fe, Mo	As, U	Mn	Cu?
C-2 Black ore, "C" level	Fe, Mo	As, U		Y
C-4 Autunite-rich sample, "C" level	Fe, U		Sr, As	

The minerals that contain the arsenic, strontium, manganese, yttrium, and copper disclosed in the X-ray fluorescence spectrometer analyses have not been identified.

The "autunite-rich ore" consists chiefly of autunite, limonite, and clay minerals associated with minerals of the granodiorite host rock and their alteration products. It locally contains minute quantities of a yellow nonfluorescent uranium mineral, probably carnotite or uranophane. Stilbite forms veinlets 2 mm thick in parts of the "B" level deposit. It is in colorless prisms as much as 2 mm long, oriented perpendicular to the walls of the veinlet; in some places these are coated with autunite.

The autunite is generally in minute crystals, but autunite crystals as much as 1.5 mm across were found in a veinlet in the "B" level deposit. The crystals are thin and fragile, and tabular parallel to (001). The autunite is bright yellow and fluoresces brilliant yellow in short-wave ultraviolet light. X-ray diffraction patterns indicate that it is in the meta-autunite I phase, a lower hydrated phase due to partial dessication of natural autunite.

The light-yellow-brown aspect of the "autunite-rich" deposits is largely due to abundant limonite. Associated clay minerals are chiefly white and consist of very fine felty masses of montmorillonite and lesser amounts of illite. Opal in minute pearly botryoidal surface coatings occurs near some autunite-rich deposits. The opal is pale green and fluoresces yellow-green under short-wave ultraviolet light.

The results of uranium analyses and semiquantitative spectrographic analyses of two selected autunite-rich samples are shown in table 6.

Table 6.--Results of chemical and equivalent uranium analyses, and semiquantitative spectrographic analyses of selected ore specimens from the Kergon mine.[1]

Number and location	Percent chemical U	Percent equivalent U	Percent											
			>10	5-10	1-5	.5-1	.1-.5	.05-.1	.01-.05	.005-.01	.001-.005	.0005-.001	.0001-.0005	.00005-.0001
K-7 "Charley's cut"	.47 .51	.25 .27	Al, Si		Na, Fe, Ca, K, Mg	Ti	U	Ba, Sr	Li, V, Mn	B, Cr, Cu	Sc, Ga, Zr, Pb	--	--	Be
K-30 "B" level ore body	10.0 10.3	6.3 7.8	Al, Si	U	Fe, Ca	K, Mg, Na	P, Ti	Ba, Sr,	Cd, V, Y, Li	Mn, B, Nd, Gd, Ni	Cu, Yb, La, Ga, Eu, Ho, Tm, Pb	Sc, Zr, Cr, Mo	--	Be

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[1] Spectrographic analyses by K. E. Valentine, chemical analyses by C. Johnson, radioactivity analyses by B. A. McCall, U. S. Geological Survey.

Aside from the obvious increase in uranium, the "autunite-rich ore" is not very different in composition from representative Isabella granodiorites (table 3). Specimen K-7 contains slightly abnormal amounts of titanium and vanadium. Specimen K-30 contains abnormal amounts of phosphorous and vanadium, but is deficient in potassium and sodium. Results of X-ray fluorescence spectrometer analyses of three autunite-rich samples are shown in table 5. The arsenic and copper content suggests the presence of small amounts of metazeunerite.

Wall-rock alteration

Argillic wall-rock alteration, characterized by bleached montmorillonite-rich zones, is general alongside the uranium deposits, and is best exposed adjacent to both shear zones in "Charley's cut" (fig. 9). The altered zones are a few inches to about 3 feet thick. Argillic alteration accompanies most uranium deposits of the Kergon shear zone. It is most intense near fractures in the shear zone, and fades out away from the shear zone. In the "C" level ore body, clay minerals form a crude halo, about 2 feet thick around "black ore" and "autunite-rich ore".

Miracle mine

Location and accessibility

The Miracle mine is in secs. 17 and 20, T. 27 S., R. 32 E., on the steep south slope of Kern River Canyon. It is in the south-central part of the area about a mile west of Miracle Hot Springs (pl. 1, fig. 1). The mine area is about 2,200 feet to 3,100 feet above sea level (pl. 3); it is crossed by State Highway 178 and is readily accessible.

History and production

Uranium was first discovered in the Kern River uranium area at the site of the Miracle mine, in January 1954, by Henry Brooks Mann and associates of Taft, California. These prospectors, using a carborne scintillation counter, detected the abnormal radioactivity of the Miracle shear zone while traversing State Highway 178. Mann and his associates thereupon commenced mining, and on July 31, 1954, they shipped a 46-ton carload of ore that averaged 0.53 percent uranium to the Vitro Uranium Co. at Salt Lake City. This ore was mined from the northernmost 100 feet of the main adit. The adit was driven a total length of 255 feet before the locators sold the property in September 1954 (Walker, Lovering, and Stephens, 1956, p. 30). The new owners extended the adit, drove minor crosscuts, and excavated most of the numerous surface cuts and trenches.

On June 21, 1955 an 85,360-pound ore shipment containing 0.16 percent uranium and 0.06 percent vanadium was made to the Vitro Uranium Co._/

_/ Production data published with permission of the mine owners, the Miracle Springs Mining Corporation.

This shipment contained material mined between 50 and 75 feet from the portal of the main adit, and also from cut C-2.

Workings

The main adit and associated workings are the only important underground excavations; several adits have been started but the longest extends only 16 feet. The main adit extends 380 feet S. 33° E. along the Miracle shear zone (fig. 11). Associated workings are a winze 8 feet deep near the portal of the adit, a minor overhand stope 85 to 100 feet from the portal, and three short crosscuts that aggregate 34 feet in length. The surface workings include many bulldozer cuts, shallow pits, and trenches (plate 3, figure 12). Only workings at sites of significant radioactivity will be described, and these are shown in figures 13 and 14.

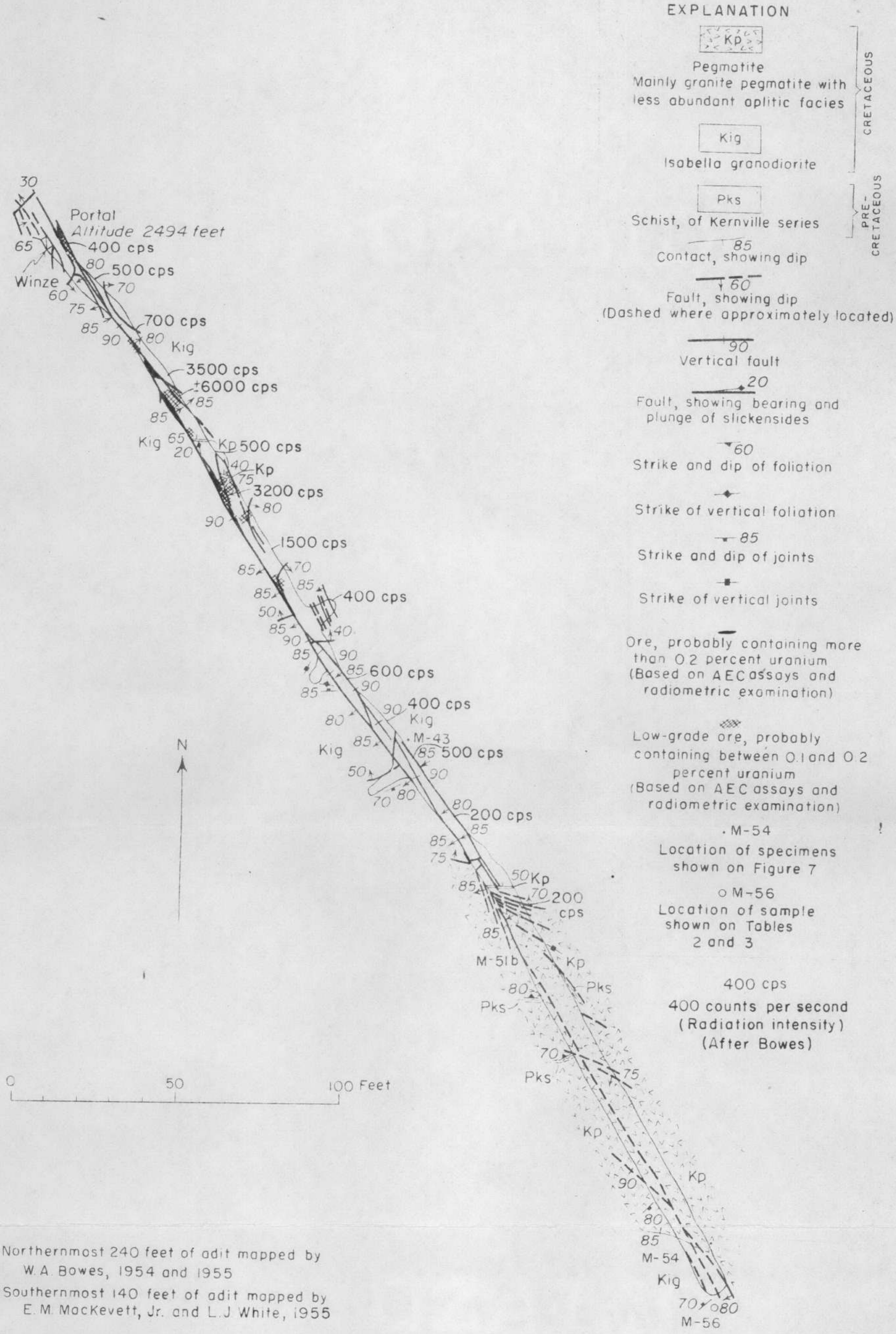
Cuts C-1, C-2, C-3, C-4, and C-5 (fig. 13) are mainly on the Miracle shear zone or subsidiary affiliated fractures generally in granodiorite. Recent work has extended cut C-2 about 10 feet farther to the southeast than is shown in figure 13.

Cuts no. 9 and no. 10 are on the same structure, a steep-dipping shear zone striking N. 40° W., in weathered granodiorite (fig. 14).

The two no. 11 cuts (fig 14) are mainly on separate northwest-trending faults that cut granodiorite.

Geology of the Miracle area

The Miracle mine area is underlain by rocks of the Isabella granodiorite mass and many pegmatite dikes. Xenotime was identified either questionably or assuredly in all thin sections of specimens of granodiorite from the Miracle mine area, and the four analyzed samples



Northernmost 240 feet of adit mapped by W. A. Bowes, 1954 and 1955

Southernmost 140 feet of adit mapped by E. M. MacKevett, Jr. and L. J. White, 1955

Figure 11. Geologic map of the main adit, Miracle Mine

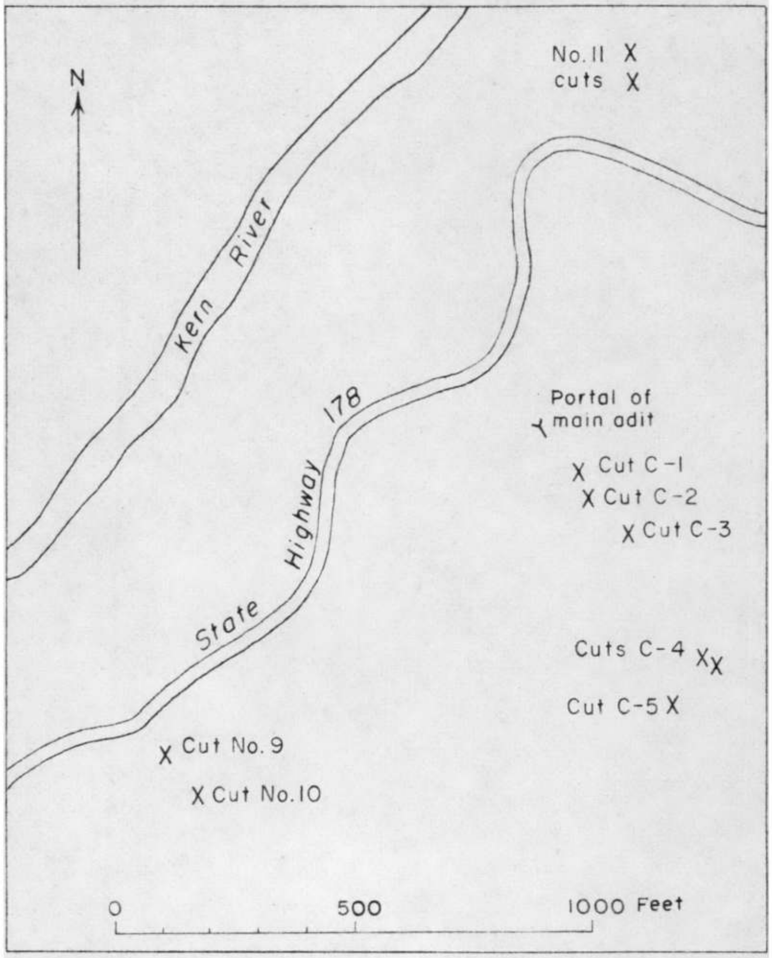
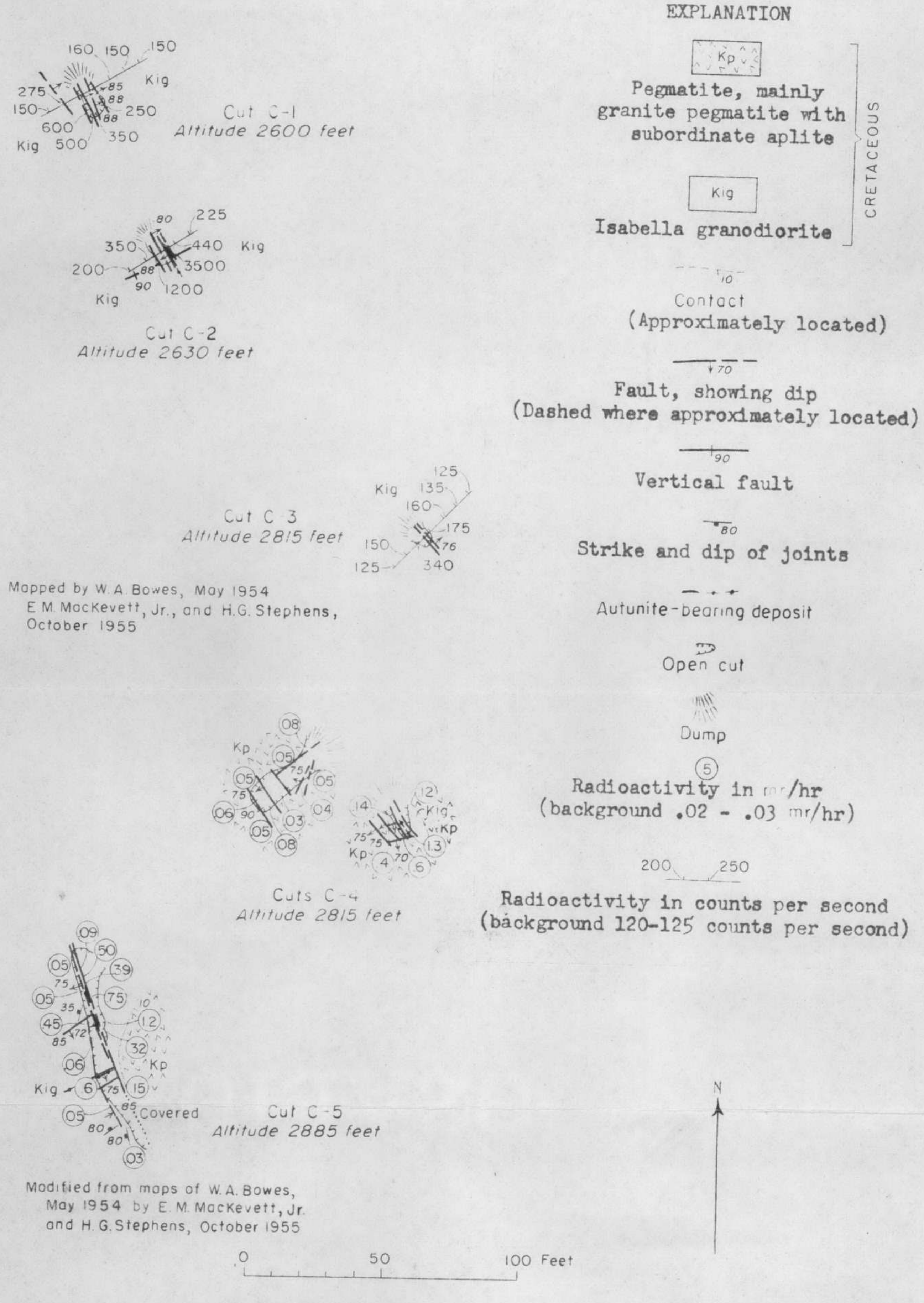


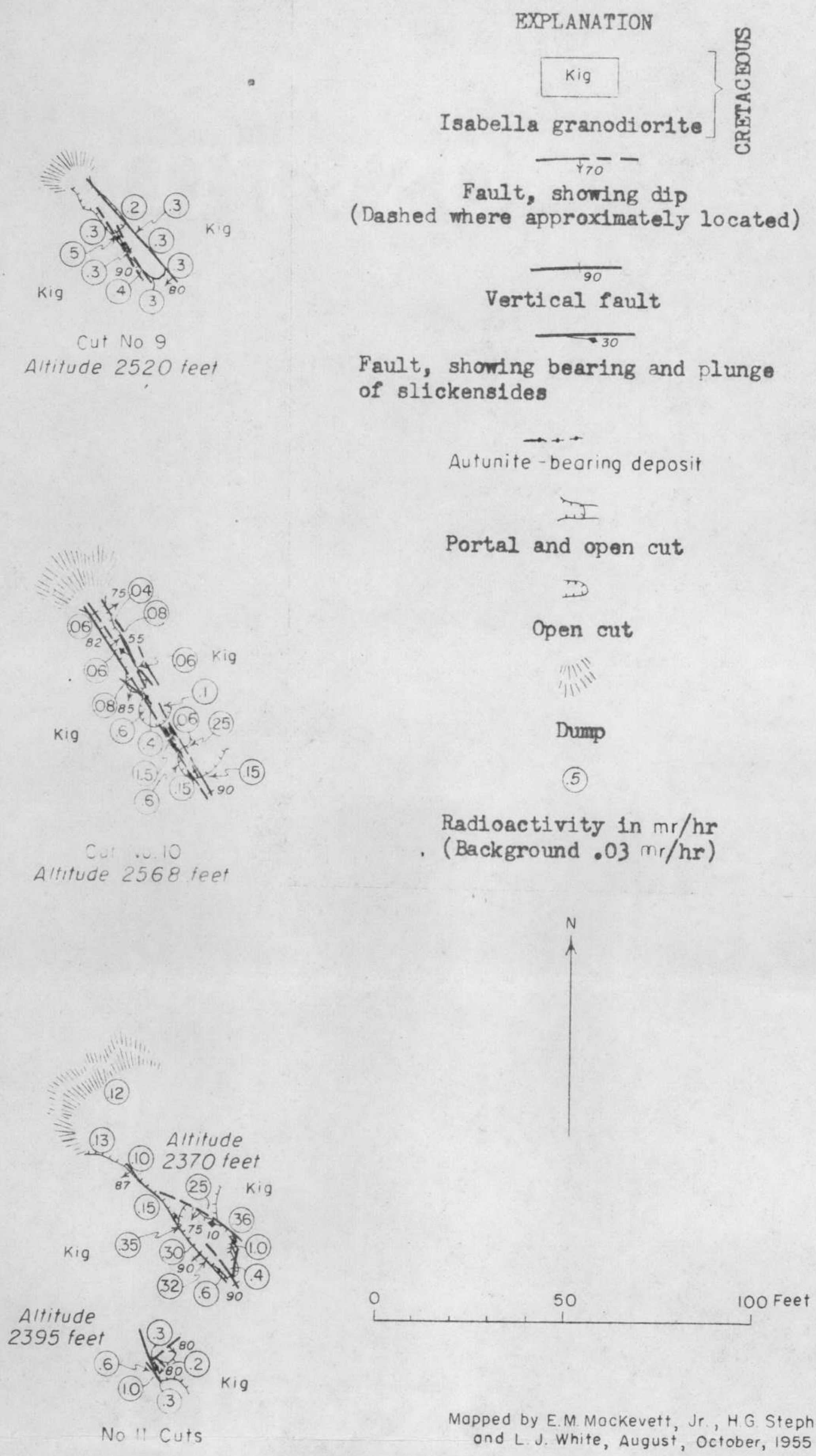
Figure 12. Index map showing location of the main surface workings in the Miracle Mine area



Mapped by W. A. Bowes, May 1954
E. M. MacKevett, Jr., and H. G. Stephens,
October 1955

Modified from maps of W. A. Bowes,
May 1954 by E. M. MacKevett, Jr.
and H. G. Stephens, October 1955

Figure 13. Geologic map of Cuts C-1, C-2, C-3, C-4, and C-5, Miracle mine



Mapped by E. M. MacKevett, Jr., H. G. Stephens, and L. J. White, August, October, 1955

Figure 14. Geologic map of nos. 9, 10, and 11 cuts, Miracle Mine

of these rocks (table 9) each contained 20 ppm uranium, or about five times as much as average granitic rock. Mafic inclusions in the Isabella granodiorite are abundant in the mine area.

The numerous pegmatite dikes, which are allied in composition chiefly to granite but partly to quartz monzonite, contain the minerals typical of other pegmatites in the general area. A few fracture surfaces in the pegmatites are thinly coated with pale-green botryoidal opal. The dikes range in thickness from 2 or 3 inches to about 180 feet, and attain outcrop lengths up to several thousand feet. The Miracle pegmatite dike, the largest dike in the mine area, is exposed for a length of about 2 miles and is near 180 feet in maximum thickness. It contains widely scattered inclusions of schist up to 30 feet long derived from the Kernville series.

The dominant fracture sets, represented by joints, faults, and shear zones, are steep and strike either N. 20° to 40° W. or N. 60° to 80° E. The Miracle shear zone, the principal structural feature of the mine area, splits toward the south into numerous, generally weaker fractures. Where this shear zone crossed the competent Miracle pegmatite, the rock cracked readily and many sharp, clean fractures that vary irregularly in attitude (fig. 11) were formed. Shear zones similar in attitude to the Miracle shear zone cut the Isabella granodiorite in cuts 9, 10, and 11 (pl. 3). Near cuts 9 and 10 (fig. 14), a shear zone generally 4 or 5 feet thick and containing from three to five individual fractures is traceable for about 180 feet on the surface. It strikes N. 40° W. and is made up of fractures that dip from 75° NE to 80° SW. Slickensides on one of the prominent fault surfaces in cut no. 10 plunge 55° NW.

Two shear zones crop out in the no. 11 cuts (pl. 3, fig. 14). They generally trend N. 20° to 40° W. are nearly vertical, and are traceable to the southeast for about 250 feet. Northward extensions are difficult to follow, but may be represented by a shear zone of similar trend exposed for several hundred feet north of the Kern River.

Faults of the northeast-striking sets are commonly not recognizable for more than 100 feet along the strike. They are represented by faults in cuts C-2, C-4, and C-5 and elsewhere, notably along the south side of Highway 178 in the western part of the mine area.

Numerous planar structures, best indicated by the alinement of inclusions, generally strike N. 65° E. to E. and dip steeply south. Lineations, marked by hornblende and biotite alined in flow planes, commonly plunge steeply southwest where observed.

Uranium deposits

The uranium deposits of the Miracle mine are chiefly in the Miracle shear zone, and in associated divergent fractures near its southern end. Northwest-striking shear zones similar to the Miracle shear zone localize uranium deposits at cuts 9, 10, and 11. There are small bodies of uranium-bearing material in some of the northeast-striking, steep-dipping faults, principally near intersections with components of the Miracle shear zone. The uranium deposits are irregularly distributed along the controlling structures, and are separated by wide barren gaps or by zones of sparsely dispersed uranium minerals. The deposits are highly oxidized and are commonly associated with limonite. Secondary uranium minerals, dominantly autunite, occur in small pods, in coatings on gouge and wallrock, in erratic disseminations in gouge, in weathered and altered wallrock, and rarely in minute veinlets.

Deposits in the Miracle shear zone and associated fractures.--Most of the uranium deposits are localized in the strongly fractured medial parts of the Miracle shear zone where it crosses weathered granodiorite. There are many small deposits along divergent fissures that make up the southern part of the shear zone.

The larger deposits in the Miracle mine are exposed intermittently along the northernmost 130 feet of the main adit (fig. 11). They are individually from a few inches to about 5 feet thick, and the longest is about 27 feet long. The richest deposit was in the back of the adit, 45 to 72 feet from the portal. Most of the ore bodies are localized along a strong nearly vertical fault that coincides with part of the west wall of the adit (fig. 11). Local slickensides on this fault plunge about 20° N. In some places the intersections of lesser divergent fractures with the main through-going fractures apparently formed loci for the deposition of ore. Most of the deposits are in weathered and locally slightly altered granodiorite. Uranium minerals are uncommon in the southernmost 250 feet of the adit where the fractures of the shear zone are less intense and diverge.

Radiation intensities, as recorded by W. A. Bowes of the U. S. Atomic Energy Commission, in counts per second for the northernmost 256 feet of the Miracle adit are shown by Walker, Lovering, and Stephens (1956, p. 29, fig. 4) and in figure 11 of this report. The highest values were about 6000 counts per second against a background of 160 counts per second. Radioactivity in the southernmost 124 feet of the adit is insignificant. The grade of the deposits is indicated by the two shipments, mainly from the northernmost 100 feet of the main adit. The first shipment contained 0.53 percent uranium, and the second shipment contained 0.16 percent uranium and 0.06 percent vanadium. Further indications of grade are given by U. S. Atomic Energy Commission assays. Grab samples collected near the adit portal contained as much as 0.41 percent uranium (Walker, Lovering, and Stephens, 1956, p. 30). Samples taken from bodies 1.0 to 2.5 feet long in the northernmost 50 feet of the adit contained 0.8 and 0.30 percent uranium. A sample from a cut across the 1.5-foot long high-grade ore body between 55 and 75 feet from the portal contained 1.39 percent uranium, and two samples each representing nine-tenths of a foot from the same ore body assayed 7.6 percent and 4.7 percent uranium. Other samples taken in nearby parts of the ore body assayed 0.12 and 0.19 percent uranium, indicating abrupt fluctuations in tenor in short distances. In the interval between 75 and 130 feet from the portal, assay values range between 0.09 and 0.96 percent uranium and average near 0.20 percent. Most samples from the southernmost 250 feet of the adit yielded less than 0.05 percent uranium.

Deposits in cuts C-1, C-2, and C-3 are on iron-stained multiple faults of the Miracle shear zone and chiefly in coatings on gouge and weathered granodiorite. Radioactivity from these deposits, in counts per second, is shown in figure 13. The highest count, 3500 counts per second against a background of 125 counts per second, was recorded from C-2. Atomic Energy Commission assays show that a 3-foot long sample from cut C-1 contained

0.014 percent uranium, a sample 2 feet long from cut C-2 contained 0.23 percent uranium, and a sample 1 foot long from cut C-3 yielded 0.013 percent uranium. Part of the second ore shipment was from cut C-2.

Anomalous radioactivity was detected in the C-4 cuts (fig. 13), mainly on tight fractures that branch from the Miracle shear zone and cut pegmatite. Radioactivity as great as 1.3 mr/hr, against a background of 0.02 to 0.03 mr/hr, was detected in the easternmost C-4 cut. The greatest radioactivity in the westernmost C-4 cut is only three or four times the background count.

In cut C-5 autunite is irregularly distributed along faults of the Miracle shear zone for a strike length of about 40 feet (fig. 13). Most of the deposits there are accompanied by iron staining and are in weathered granodiorite. Anomalous radioactive emanations from the deposits range from 0.05 to 1.2 mr/hr against a background rate between 0.02 and 0.03 mr/hr. Uranium minerals in a fracture of the Miracle shear zone in the trench about 100 feet southeast of cut C-5 (pl. 3) emit radiations three or four times the background magnitude.

In the cut about 100 feet northwest of the highway autunite in the Miracle shear zone is spottily distributed along two major fractures. A select sample assayed 1.00 percent uranium. Chip samples about 4 feet long cut across the shear zone at the cut contained 0.042 and 0.076 percent uranium (table 8).

Deposits associated with other faults.--In cuts nos. 9 and 10 uranium minerals are distributed along constituent fissures of a shear zone for about 130 feet (pl. 3, fig. 14). The country rock is weathered granodiorite.

In the no. 9 cut and adit, uranium-bearing deposits 1 to 3 inches thick and up to 20 feet long were found on each of the three northwest-trending faults cut by the workings. The maximum radioactivity associated with these deposits was 0.5 mr/hr, with a background of 0.03 mr/hr. Scattered uranium deposits are on the northwest-trending faults of cut no. 10. The principal deposit is in the pits southwest of the cut and emits anomalous radioactivity as great as 50 times that of the background. The deposit is approximately 15 feet long and 2 feet thick.

In the no. 11 cuts (fig. 14) secondary uranium minerals are associated with northwest-trending faults. Although anomalous radioactivity is detectable for a strike length of 40 feet along one of the faults, the deposits are sporadic and generally only an inch or two thick. Maximum radioactivity in both the upper and lower no. 11 cuts is 1.0 mr/hr; background radioactivity 0.03 mr/hr. Analyses of chip samples from the no. 11 cuts are shown in table 8. The samples are between 2 and 4 feet long and include wall-rock granodiorite that is intermixed with uraniferous material. The highest assay values--0.20 and 0.16 percent uranium--were from samples collected near the southeast end of the lower no. 11 cut, where multiple iron-stained and gouge-coated fractures served as loci for erratic uranium deposition.

Minor abnormally radioactive deposits occur along many of the northeast-trending fractures in the area, notably at cuts C-4 and C-5, the upper no. 11 cut, and the trench about 100 feet southeast of cut C-5. Up to 1956 little exploration had been done on these deposits, and they had been opened only near intersections with northwest-trending faults. Most of these uranium occurrences are on steep-dipping faults that strike N. 50° to 80° E., although a few of the host faults trend more nearly north. The N. 68° E.-striking, 75° SE-dipping shear in cut C-5 (fig. 13) contains irregular deposits of autunite over a thickness of 3 feet--probably the best uranium deposit in a northeast-trending structure on the property. Its radioactivity is about 25 times as great as the background.

Mineralogy and composition.--The uranium deposits in the Miracle mine area are very fine grained assemblages of secondary uranium minerals, occurring as thin surface coatings, as minor disseminations and impregnations in gouge and wall rock, and, in small part, as very thin veinlets. They are almost everywhere stained with iron oxides, and are generally associated with clay minerals probably formed in part by hydrothermal alteration and in part by near-surface weathering of the granodiorite. Wall-rock alteration, however, is notably slight, and the common gangue minerals are unusually scarce.

Autunite is the prevalent uranium mineral, and is found in all the deposits. It forms minute pale yellow-green crystals that fluoresce bright yellow-green in short-wave ultraviolet light. Intermixed with the autunite is a yellow, non-fluorescent crystalline material that is probably carnotite; this occurs in the C-2 cut deposit, and less commonly in other places (tables 7, 8) where analyses generally indicate an abnormal vanadium content. Scattered small dark-gray to black pods consisting of sooty pitchblende and "gummite" were reportedly mined from the ore body between 50 and 60 feet from the adit portal (W. A. Bowes, U. S. Atomic Energy Commission, 1955, oral communication). Unfortunately, however, none of this material was available during the present study. According to geologists of the U. S. Atomic Energy Commission small amounts of fluorite were found in some of the deposits in the main adit (Walker, Lovering, and Stephens, 1956, p. 30).

The chemical composition of the deposits is indicated in tables 7 and 8. The samples shown in table 7 are selected uranium-bearing specimens with a minimum of barren wall rock. The analyses indicate a general increase in vanadium content with an increase in uranium--a fact that has been noted for the Miracle mine by R. P. Fischer (written communication)--and they commonly record the presence of strontium, arsenic, gallium, and antimony which are mineralogically unaccounted for.

Table 8 represents chip samples from 1 to 4 feet long that include the thin uraniferous zones and the adjacent generally weathered or altered wall rock. The samples are generally similar in composition to fresh and weathered Isabella granodiorite (table 3), except that they all contain more uranium, and most of them more molybdenum, vanadium, gallium, and nickel.

Wayne Case prospects

The Wayne Case prospects are on the Eureka group of claims in secs. 19 and 20, T. 27 S., R. 32 E., bordering the Kergon mine on the southwest (pl. 1). The claims were located during the summer of 1954 by Wayne Case of Taft, California. The best deposits appear to be on the Eureka no. 13 claim in an open cut about half a mile S. 40° W. of the Kergon adit portal (pl. 1). This cut, which trends S. 35° E., is 20 feet long, 15 feet deep at its southeast face, and about 4 feet wide. Scattered autunite deposits are localized in a steep iron-stained shear zone that strikes N. 35° W. The shear zone cuts granodiorite, in which there is local weak argillic alteration. The uranium deposits are thin and irregular. Selected samples assayed by the U. S. Atomic Energy

(Text is continued on page 91.)

Table 7.--Results of X-ray fluorescence spectrometer analyses of some uranium-bearing samples from the Miracle mine area.

	Relative quantity in sample			
Number and location	Strong	Moderate	Weak	Trace
M-3 C-2 cut	Fe, U	V	Sr, As, Ga	Sb, Ag(?), Mn
M-37 No. 10 cut	Fe		Sb, U Ga	Ag(?), Sr, Rb, As, Mn, V
M-39 No. 10 cut	Fe	Sr	U, As, Ga	Sb, Y, Mn, Ti
M-40 No. 11 cut	Fe	U	Sr	Cd, Zr, Rb(?), As, Ga, Mn, Cu(?)
M-46 Main adit, 47 feet from portal	Fe, U		V	As, Ga, Sr

Table 8.--Results of chemical and equivalent uranium analyses and semiquantitative spectrographic analyses of uraniferous chip samples from the Miracle mine area. Spectrographic analysis--M. Frank, chemical analysis--R. Moore, radioactivity analysis--B. A. McCall

Number and location	Percent													
	chemical U	equivalent U	>10	5-10	1-5	.5-1	.1-.5	.05-.1	.01-.05	.005-.01	.001-.005	.0005-.001	.0001-.0005	.00005-.0001
1-0 cut about 100 ft SE of C-5 cut	.018	.020	Si, Al		K, Na, Fe, Ca, Mg		Ti, Ba	Sr	B, Mn	V, Ga, Ni, Y	Cr, La, Pb, Zr, Co, Cu, Sc	Mo, Yb		Be
2-0 C-5 cut	.038	.036	Si, Al		Fe, K Na, Ca, Mg		Ti, Ba	Sr	B, Mn	V, Ga Ni	Cr, Y, Zr, Co, Pb, Cu, Sc	Mo	Yb	Be
4-1 lower No. 11 cut	.20	.17	Si, Al		Na, Ca, Fe, K, Mg		U, Ti, Ba	Sr	B, Mn	V, Ga Ni	Cr, La, Y, Zr, Co, Pb, Cu, Mo, Sc	Yb		Be
4-2 lower No. 11 cut	.16	.15	Si, Al		Ca, K, Fe, Na	Mg	U, Ba, Ti	Sr	Mo, B, Mn	V, Ga, Ni	La, Y, Cr, Zr, Cu, Pb, Co, Sc		Yb	Be
5-1 upper No. 11 cut	.056	.056	Si, Al		Ca, Fe, K, Na, Mg		Ti, Ba	Sr	Mo, B, Mn	V, Ga, Ni	Cr, Y, Zr, Co, Cu, Pb, Sc		Yb	Be

Table 8.--Results of chemical and equivalent uranium analyses and semiquantitative spectrographic analyses of uraniferous chip samples from the Miracle mine area.--Continued. Spectrographic analysis--M. Frank, chemical analysis--R. Moore, radioactivity analysis--B. A. McCall.

Number and location	Percent chemical U	Percent equivalent U	>10	5-10	1-5	.5-1	.1-.5	.05-.1	.01-.05	.005-.01	.001-.005	.0005-.001	.0001-.0005	.00005-.0001
5-2 upper No. 11 cut	.038	.037	Si, Al		Ca, Fe, K, Na, Mg		Ti, Ba	Sr	B, Mn	V, Zr, Ga, Ni	Cr, Y, Cu, Co, Pb, Sc	Mo	Yb	Be
6-1 cut on Miracle shear zone below highway	.042	.040	Si, Al		Na, Ca, Fe, K	Mg	Ba, Ti	Sr	V, B, Mn	Ga, Ni, Zr	La, Y, Cr, Pb, Sc, Co, Cu	Mo	Yb	
6-2 cut on Miracle shear zone below highway	.076	.078	Si, Al		K, Na, Ca, Fe	Mg	Ba, Ti	Sr	V, B, Mn	Ga, Ni	Y, Zr, Cr, Pb, Sc, Co, Cu	Mo	Yb	

Commission contained as much as 0.40 percent equivalent uranium and 0.52 percent chemical uranium (Walker, Lovering, and Stephens, 1956, p. 30), but more representative samples contained considerably less uranium.

Last Chance prospect

The Last Chance prospect, owned by Robert Martin of Miracle Hot Springs, is in the pendant of Kernville series metamorphic rocks about a quarter of a mile east of Miracle Hot Springs, in sec. 15, T. 27 S., R. 32 E. (pl. 1). It is primarily a tungsten prospect. Its workings consist of two irregular, shallow surface pits, about 20 feet in maximum diameter. The country rock, which is iron-stained calc-hornfels and tactite, locally emits anomalous radioactivity. Radioactivity measurements by the U. S. Atomic Energy Commission were as much as 10 times the background rate, but selected samples yielded less than 0.047 percent uranium (Walker, Lovering, and Stephens, 1956, p. 30). No uranium minerals have been identified in this deposit.

Monte Cristo prospect

The Monte Cristo prospect, owned by Lenwood Barnes of Taft, California, lies in sec. 19, T. 27 S., R. 32 E., at altitudes near 2,700 feet (pl. 1). A small pit exposes two parallel veins in granodiorite that strike N. 60° W. and dip 80° SW. The veins are about 0.5 feet in maximum thickness and traceable for about 20 feet. They consist predominantly of coarse calcite that contains carnotite-rich layers less than 0.5 mm thick. Minor amounts of autunite are associated with the carnotite. Vugs in the veins are lined with calcite crystals, some of which are coated with carnotite.

Little Sparkler prospect

The Little Sparkler prospect is in sec. 17, T. 27 S., R. 32 E., 2,400 to 2,850 feet above sea level (pl. 1). The property was located during 1954 by A. B. Scouler and associates, but little work was done on it until 1956, after the field investigations leading to this report had been made. W. A. Bowes (oral communication, 1956) of the U. S. Atomic Energy Commission reports that during the summer of 1956 small deposits of uranium minerals were exposed in small test pits on the prospect, along a steep northwest-trending fracture that cuts granodiorite and pegmatite. The fracture may represent an extension of the shear zone exposed in the Miracle nos. 9 and 10 cuts. Metazeunerite, which was identified by H. G. Stephens (oral communication, 1956), is probably the chief uranium mineral at the Little Sparkler prospect.

Other prospects

Many small workings have been excavated at sites of weak anomalous radioactivity, and most of these are shown on plate 1. These prospects commonly expose fractures in the Isabella granodiorite that contain a little uraniferous material here and there, or are in pegmatite that contains widely scattered radioactive minerals. Some of the anomalous emanations from the pegmatites are due to radioactive inclusions in biotite. Most of the lesser prospects were located during the wave of prospecting that came in 1954, and by mid-1956 many were abandoned or otherwise inactive.

The Scouler prospect (pl. 2), which is between the Miracle and Kergon mines, consists of a large bulldozer cut and two short open cuts. Anomalous radioactivity is weak in the prospect area.

Origin of the uranium deposits

Most of the uranium deposits in the Kern River uranium area, except those in pegmatites, were probably formed by low-temperature hydrothermal solutions in near-surface environments. They are believed to fit into Lindgren's (1933, p. 212) epithermal class. A hydrothermal origin is advocated because many of the constituent minerals are commonly associated with hydrothermal deposits, because wall-rock alteration accompanies some of the deposits, and because most of the deposits are localized in fractures; but the weakness of the wall-rock alteration, the sporadic distribution of the deposits, the scarcity of common gangue minerals in most of them, and the general lack of persistent veins, indicate that the deposits were formed by weak solutions. The mineralogy of the deposits indicates deposition from low-temperature, slightly alkaline solutions. These conditions are most clearly indicated by calcite, which occurs in the Monte Cristo prospect, by montmorillonite, and by stilbite, and are compatible with the other minerals in the deposits.

Most of the secondary uranium minerals in the area were probably formed by oxidation of pitchblende, as exemplified by the autunite-rich aureole surrounding the "black ore" on the "C" level in the Kergon mine. Many of the deposits are far from known primary uranium minerals, and some of these probably resulted from mobilization of uranium contained in primary minerals, transportation in aqueous solutions, and subsequent deposition in the form of oxidized uranium minerals.

Some of these uranium deposits may be genetically related to the thermal springs of the area, although D. E. White (oral communication, 1956) believes that hot-spring waters generally contain less uranium than many other types of waters. Most of the springs here emit H_2S and are not radioactive. A water temperature of 122° F was recorded for the Miracle Hot Springs, the warmest in the area. Minor amounts of H_2S issue from a trickle in a northwest-trending fracture on the south side of the Kern River, almost in line with the Miracle shear zone. Radon is believed to occur in spring water about $1\frac{1}{2}$ miles north of the Miracle mine (G. Sawyer, 1955, oral communication), and radium is reported from calcareous spring deposits about 5 miles east of the Kern River uranium area (Walker, Lovering, and Stephens, 1956, p. 31). It is conceivable that soluble uranyl $(UO_2)^{+2}$ ions could be reduced and UO_2 precipitated by the H_2S of the springs. Uranium could have been an original constituent of the spring waters, or uraniferous solutions may possibly have intermingled with the spring waters.

An example of Recent uranium deposition from an aqueous medium can be observed at the Pettit Ranch, about two-thirds of a mile northwest of the northwestern corner of the Kern River uranium area (fig. 1). At this place uranium was and is being fixed in carbonaceous matter of a mountain meadow. Analyses by the U. S. Atomic Energy Commission of water from the cold springs discharging into the meadow show an abnormal uranium content of 40 to 300 ppb, and also abnormal quantities of vanadium, molybdenum, and copper, elements which occur in some of the Kern River uranium deposits. The fact that the Pettit Ranch deposits are out of equilibrium, chemical uranium being substantially greater than equivalent uranium, and that they are in a meadow, indicates that they are young.

Possibly the uranium of some deposits was derived from the Isabella granodiorite. Results of analyses indicate that the Isabella granodiorite in the area contains abnormal amounts of uranium (table 9). Locations of samples in table 9 are shown in fig. 11 and pls. 1, 2, and 3. Samples prefixed A are from the general area (pl. 1), those prefixed K from the Kergon mine area (pl. 2), and those prefixed M from the Miracle mine area (pl. 3, fig. 11).

The uranium content of the average granitic rock as determined by testing samples from many areas is about 3 or 4 ppm, and the uranium content of the average intermediate igneous rock is slightly less (various sources cited by Larsen and Phair, 1954, p. 77); in samples of the Isabella granodiorite from the Kern River uranium area, however, it ranges from 0.001 percent to 0.003 percent--from 10 to 30 ppm.

Xenotime is probably the chief uranium carrier in the Isabella granodiorite, although some uranium may be localized on crystal surfaces and on boundaries between grains. Studies by Neuerburg (1956, p. 59) and by Brown and others (1953, p. 1400; Anonymous, 1955) indicate that about 25 percent of the primary uranium in granite is leachable, that uranium is one of the earliest-dissolved elements, and that generally about one percent of the total granite substance is leachable.

The leached uranium may have been incorporated in the ground water system and subsequently deposited in fractures, particularly in permeable shear zones, whose multitude of fractures facilitated weathering to considerable depths and also provided open spaces in which uranium compounds could be deposited. Possibly uranium minerals were precipitated where uranium-bearing ground water locally intermingled with spring water containing H_2S.

Table 9.--Results of equivalent and chemical uranium analyses of some Kern River uranium area igneous rocks.

Chemical analyses by R. Moore and C. Johnson; radioactivity determinations by B. A. McCall. Results of semiquantitative spectrographic analyses of these samples are shown in table 3, page 36.

Number and name	Percent chemical U	Percent equivalent U
A-1, Isabella granodiorite (from near type locality)	.002	.003
A-10, granodiorite	.001	.002
A-15, granodiorite	.001	.002
A-32, quartz diorite	.001	.002
A-53, granodiorite	.001	.002
A-76, quartz monzonite	.003	.002
A-89, granodiorite	.001	.002
K-2, pegmatite	.001	.003
K-17, granodiorite	.003	.004
M-28, granodiorite	.002	.002
M-30, mafic inclusion	.001	.001
M-35, granodiorite	.002	.002
M-41, granodiorite	.002	.003
M-56, weathered granodiorite	.002	.003

The Kern River uranium deposits contain elements such as Fe, Mo, As, F, and V that are common in many other uranium deposits, especially in some of those in the Colorado Plateau region.

Granodiorites in the Miracle and Kergon mine areas are higher in molybdenum than other rocks in the Kern River uranium area, and may be the source of some of the molybdenum in the Kergon deposits. They contain as much as 10 ppm molybdenum (table 3, samples prefixed M and K), whereas the molybdenum content of the average silicic rock is 2.5 ppm (Sandell and Goldich, 1943, quoted in Rankama and Sahama, 1950, p. 626).

The Kern River uranium deposits are believed to be of Quaternary age, although conclusive evidence on this point is lacking. Quaternary deposition is indicated by: (1) Recent deposition of uranium from the nearby Pettit Ranch springs; (2) the possibility that some of the uranium deposits are related to hot springs, many of which are active at the present time; (3) the deposits are out of equilibrium--a requisite but not conclusive condition for Quaternary age.

TUNGSTEN DEPOSITS

Tungsten deposits are confined to the southeastern part of the area, either within or near the metamorphic rocks of the Kernville series. Scheelite, the only ore mineral in the deposits, occurs both in tactite and in hypothermal quartz veins that resemble silexite. The scheelite is irregularly distributed in both types of deposits.

There are many small scheelite mines and prospects close to the southeastern boundary of the Kern River uranium area, but only the Prosperity mine and some minor prospects are actually within its boundary. The Prosperity mine (pl. 1), located in 1936, consists of a 35-foot crosscut adit, a few hundred feet of drifts, an open cut about 200 feet long and 40 feet in maximum depth, and lesser surface excavations. The workings are mainly in metamorphic rocks near their contact with the Isabella granodiorite.

Intermittent minor production has come from a scheelite-bearing quartz vein about 4 feet thick that strikes N. 10° E. and dips 72° NW. Scheelite is irregularly disseminated in the vein as crystals ranging from less than 1 mm to about 5 mm in diameter. The vein also contains a little pyrite, limonite, and chlorite(?). Tucker and Sampson (1940, p. 333) report that some ore from this property contained about 1 percent WO_3.

GOLD DEPOSITS

The first gold discovery in Kern County was made in 1851 in the Kern River uranium area by a member of Fremont's party at Greenhorn Creek near the Kern River (Brown, 1915, p. 481). Historically, gold has been the chief magnet for prospecting in the area. Gold prospects and inactive mines are widespread, particularly north of the Kern River, but in 1956 there was little interest in gold mining in the area. Both placer and lode deposits are represented. Placer gold was localized in channels in the Kern River and in river terrace gravels, and in at least one locality, the Greenhorn Caves placer deposit, it occurs in gravels in a crevice cutting granodiorite. The Greenhorn Caves placer deposit includes large tracts mainly next to the west central border of the area in secs. 12, 13, and 24, T. 27 S., R. 31 E. Tucker, Sampson, and Oakeshott (1949, p. 233) say that this deposit is supposed to have yielded $60,000.

The lode deposits consist of quartz stringers and pods localized along faults. Some of the deposits contain limonite, and small amounts of pyrite or arsenopyrite or both. The mines and prospects are mostly inaccessible, but according to California State Division of Mines reports and supplementary visual estimates of volumes of dump material, the underground workings of individual properties are generally no more than three or four hundred feet in extent.

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EXPLANATION

Quartz vein or silexite dike
(Dashed where approximately located)

Pegmatite, showing dip
(Dashed where approximately located)

Vertical pegmatite
(Dashed where approximately located

Kig

Isabella granodiorite
(Mainly granodiorite, subordinate quartz
monzonite and quartz diorite)

Kd

Diorite and related rocks

Pks

Kernville series
(Mainly mica schist and impure quartzite,
subordinate calc-hornfels and marble)

CRETACEOUS

PRE-CRETACEOUS

Contact, showing dip
(Dashed where approximately located)

Fault, showing dip
(Dashed where approximately located)

Vertical fault

Fault, showing bearing and
plunge of slickensides

Fissures, plotted from aerial photographs
(These are believed to represent steep-
dipping fractures, mainly joints)

Plunge of minor anticline

Strike and dip of beds

Strike of vertical beds

Strike and dip of planer structure in
Isabella granodiorite

Strike of vertical planer structure in
Isabella granodiorite

Strike and dip of foliation in Kernville
series

Strike of vertical foliation in Kernville
series

Strike and dip of joints

Strike of vertical joints

Small mine or prospect
U - uranium, Au - gold, W - tungsten
(Prospects without letter symbols are
probably mainly for uranium).

(.04)

Radioactivity anomaly in mr/hr,
background .02 - .03 mr/hr
(These valves represent maximum surface
readings obtained during a general
reconnaissance for radioactivity)

A-5

Location of Isabella granodiorite specimens
whose thin sections are represented in figure 5.

A-10

Location of specimens for which semiquantitative
spectrographic analyses and chemical uranium
analyses were made (see tables 3 and 9).

A-76

Location of specimen whose thin section is
represented in figure 5, and which also
has been analized chemically for uranium
and spectrographically (see tables 3 and).

Topography enlarged from U.S. Geological Survey
15 minute Glennville quadrangle, in preparation

Geology by E. M. MacKevett, Jr. and H. G. Stephens, 1955

GEOLOGIC MAP
OF THE
KERN RIVER URANIUM AREA, KERN COUNTY, CALIFORNIA

Scale $\frac{1}{20,000}$

1 0 1 Mile

Contour interval 80 feet
Datum is mean sea level

Plate 1

Geology by E. M. MacKevett, Jr., 1955

Topography by E. M. MacKevett, Jr., L. J. White, and H. G. Stephens, 1955

GEOLOGIC MAP OF THE KERGON MINE AREA, KERN COUNTY, CALIFORNIA

200 0 200 400 Feet

Contour interval 25 feet

Datum is mean sea level

Plate 2

Geology by E. M. MacKevett, Jr., 1955

Topography by E. M. MacKevett, Jr., L. J. White, and H. G. Stephens, 1955

GEOLOGIC MAP OF THE MIRACLE MINE AREA, KERN COUNTY, CALIFORNIA

200 0 200 400 Feet

Contour interval 25 feet

Datum is mean sea level

Plate 3

EXPLANATION

CRETACEOUS

Kp

Pegmatite
(Mainly granite pegmatite, subordinate aplite, dashed where approximately located)

Kig

Isabella granodiorite

PRE-CRETACEOUS

schist

Schist of Kernville series

30

Contact, showing dip
(Dashed where approximately located, dotted where concealed)

70

Fault, showing dip
(Dashed where approximately located, dotted where concealed)

90

Vertical fault

Fault, showing relative movement

30

Strike and dip of internal structures in pegmatite

70

Strike and dip of planar structure

Strike of vertical planar structure

80

Strike and dip of joints

Strike of vertical joints

Portal of adit

Portal and open cut

Prospect pit

Open cut

Bulldozer cut

Underground workings
(Projected to surface)

Dump

(06)

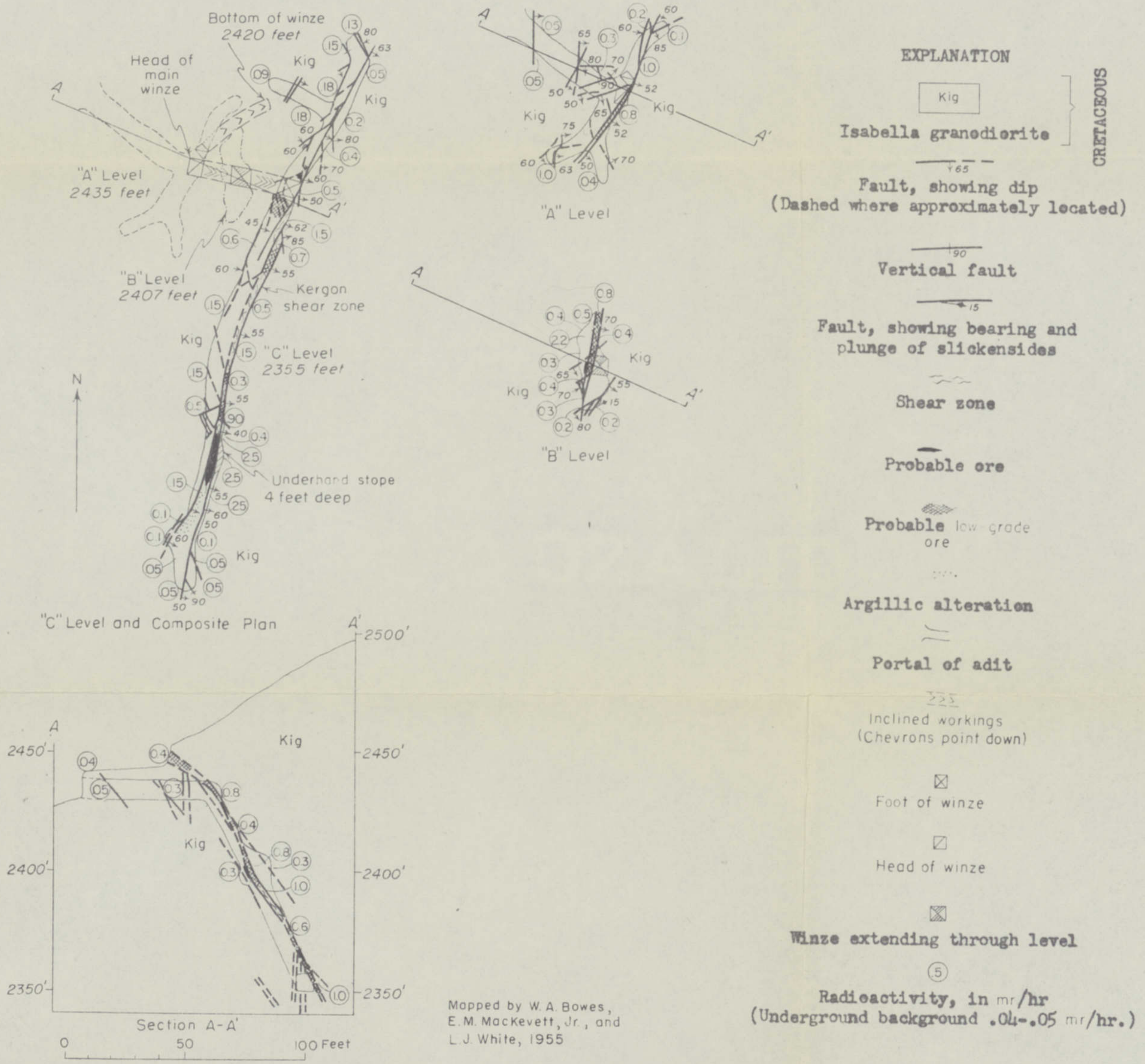
Radioactivity anomaly in mr/hr.
(Background .02-.03 mr/hr.)

• M-6

Location of rock specimen whose thin section is graphically depicted in figure 6

○ M-30

Location of rock specimen that has been semiquantitatively spectrographically analyzed (table 3) and analyzed for chemical and equivalent uranium (table 9).



Mapped by W. A. Bowes, E. M. MacKevett, Jr., and L. J. White, 1955

Figure 8. Composite plan, geologic maps, and geologic section of underground workings at the Kergon Mine